QD
41
S988m
1889

QD 41 S988m 1889

04530760R

NLM 05029752 4

NATIONAL LIBRARY OF MEDICINE

SURGEON GENERAL'S OFFICE

LIBRARY.

~~ANNEX~~

Section, Chemistry

No. 126136

A MANUAL
—OF—
CHEMISTRY
FOR THE USE OF
MEDICAL STUDENTS

—BY—

BRANDRETH SYMONDS, A.M., M.D.,

Assistant Physician to Roosevelt Hospital, Out-Patient Department.
Attending Physician, Northwestern Dispensary,
NEW YORK.

SURGEON GEN'L'S OFFICE
126136
LIBRARY

PHILADELPHIA:
P. BLAKISTON, SON & CO.,
1012 WALNUT STREET.
1889.

Annex
QD
41
S988m
1889

Film no. 11059, item 5

Entered according to Act of Congress, in the year 1889, by

BRANDRETH SYMONDS,

in the Office of the Librarian of Congress.

PUSEY & CO. PRINTERS, 1398 BROADWAY, N Y.

TO THE MEMORY

OF

MY FRIEND AND COUNSELLOR,

E. DARWIN HUDSON, JR., A.M., M.D.

PREFACE.

ALTHOUGH this Manual is intended for the use of medical students, it is not designed to be a medical chemistry. Rather, it takes up those parts of General Chemistry which it is necessary for them to know. As I have prepared students for several years in this branch, both for their degrees and for entrance into the Government medical services, I feel that I know their needs. I have derived much assistance from the lectures of Prof. C. F. Chandler and his published articles in preparing this work, especially as regards Chapters IV and V. The tests for the important substances have been grouped together in Chapter X. In Chapter XI is given a brief account of the urine and the tests for the more important substances occurring in it. The theories of to-day concerning chemical action are briefly presented in Chapter XII. While the omissions have necessarily been many and important, I hope the errors will be found to be few and of little consequence.

I take this opportunity to thank Mr. Walter Bensel for assistance rendered during the publishing of the book and in the preparation of the index. B. S.

NEW YORK, May 7, 1889.

CONTENTS.

PAGE.

CHAPTER I. NON-METALLIC ELEMENTS, - - 3

" II. " " (*Continued*), 14

" III. " " (*Continued*), 19

" IV. WATER, - - - - - 26

" V. AIR, - - - - - - - 38

" VI. CHEMICAL NOMENCLATURE, - 45

" VII. GRAPHIC FORMULÆ, - - - 51

" VIII. METALS, - - - - - 58

" IX. ORGANIC CHEMISTRY, - - - 96

" X. TESTS, - - - - - - 122

" XI. URINE, - - - - - - 136

" XII. CHEMICAL THEORIES, - - - 142

METRIC WEIGHTS AND MEASURES, - - - - - 148

RULES FOR CONVERTING DEGREES OF TEMPERATURE, 149

INDEX, - - - - - - - - - - - 151

LIST OF THE ELEMENTS, WITH THEIR SYMBOLS AND ATOMIC WEIGHTS. The usual atomicity of each is indicated by the Roman symbol to the right and above.

NAME.	Symbol.	Atomic Weight.	NAME.	Symbol.	Atomic Weight.
Aluminium^{iv}	Al	27.4	Mercury^{ii} (Hydrargyum)	Hg	200
Antimony^{iii} (Stibium)	Sb	122	Molybdenum^{iv}	Mo	96
Arsenic^{iii}	As	75	Nickle^{iv}	Ni	58.8
Barium^{ii}	Ba	137	Niobium^{v}	Nb	94
Beryllium^{ii}	Be	9.4	Nitrogen^{v}	N	14
Bismuth^{iii}	Bi	210	Osmium^{iv}	Os	199.2
Boron^{iii}	B	11	Oxygen^{ii}	O	16
Bromine^{i}	Br	80	Palladium^{iv}	Pd	106.6
Cadmium^{ii}	Cd	112	Phosphorus^{v}	P	31
Caesium^{i}	Cs	133	Platinum^{iv}	Pt	197.4
Calcium^{ii}	Ca	40	Potassium^{i} (Kalium)	K	39.1
Carbon^{iv}	C	12	Rhodium^{iv}	Rh	104.4
Cerium^{ii}	Ce	138	Rubidium^{i}	Rb	85.4
Chlorine^{i}	Cl	35.5	Ruthenium^{iv}	Ru	104.4
Chromium^{iv}	Cr	52.2	Selenium^{ii}	Se	79.4
Cobalt^{iv}	Co	58.8	Silicon^{iv}	Si	28
Copper^{ii} (Cuprum)	Cu	63.4	Silver^{i} (Argentum)	Ag	108
Didymium^{iii}	D	144.7	Sodium^{i} (Natrium)	Na	23
Erbium^{iii}	E	168.9	Strontium^{ii}	Sr	87.6
Fluorine^{i}	F	19	Sulphur^{ii}	S	32
Gallium^{iii}	Ga	?	Tantalum^{v}	Ta	182
Gold^{iii} (Aurum)	Au	197	Tellurium^{ii}	Te	128
Hydrogen^{i}	H	1	Thallium^{i}	Tl	204
Indium^{iii}	In	113.4	Thorinum^{iv}	Th	235
Iodine^{i}	I	127	Tin^{iv} (Stannum)	Sn	118
Iridium^{iv}	Ir	198	Titanium^{iv}	Ti	50
Iron^{iv} (Ferrum)	Fe	56	Tungsten^{iv} (Wolfram)	W	184
Lanthanum^{iii}	La	139	Uranium^{iv}	U	240
Lead^{iv} (Plumbum)	Pb	207	Vanadium^{v}	V	51 2
Lithium^{i}	Li	7	Yttrium^{iii}	Y	92.
Magnesium^{ii}	Mg	24	Zinc^{ii}	Zn	65.2
Manganese^{iv}	Mn	55	Zirconium^{iv}	Zr	89.6

Throughout the text the symbols of the elements have been used instead of the full name, thus rendering the student thoroughly familiar with them. By the term Aq is meant one molecule of water of crystallization.

CHEMISTRY.

Chemistry, as contrasted with Physics, has for its study the elements and their compounds, and the permanent changes which affect their properties and character. The elements are divided into the metals and non-metals. The former have a metallic lustre, are good conductors of heat and electricity, and are electro-positive. The latter are generally poor conductors of heat and electricity, and are electro-negative. We will first discuss the non-metals. These are:

Oxygen Selenium } These closely resemble each other and
Sulphur Tellurium } constitute the oxygen group.

Carbon Boron Silicon
Nitrogen Phosphorus

Fluorine Chlorine } Halogens
Bromine Iodine }

Arsenic Antimony } These stand between the metals and
Bismuth } non-metals. They are sometime called
} metalloids.

Hydrogen is properly a metal, but is always described with the non-metals.

CHAPTER I.

OXYGEN.—O.

History.—Discovered independently by Priestley from red oxide of Hg in 1774, and about the same time by Scheele, from black oxide of Mn; called by the former dephlogisticated air, and by the latter, empyreal air. A few years later, Lavoisier discovered that these two were the same, and he called it oxygen. He also discovered that it existed in the air by passing air over hot mercury, thus forming the red oxide.

Occurrence.—In the air in admixture, chiefly with N ; in the water in combination with H, and also in solution, the latter being what the fishes breathe ; in most minerals in combination ; in meteorites, the sun, stars and nebulæ. It exists in all plants and animals in combination.

The following is a table of the composition of plants and animals :

PLANTS.		ANIMALS.
Water.		Water.
Cellulose Starches Gums Sugars	O combined with C and H. The O and H being in the proportion to form water, they are called carbohydrates.	——* —— —— ——
Vegetable acids Fats Resins	O combined with C and H.	—— Fats. ——
Essential oils	Composed of C and H.	——
Albumenoids Alkaloids	O combined with N, H, C, and sometimes S.	Albumenoids. Alkaloids.
Mineral salts	Chlorides Sulphates Nitrates Phosphates Carbonates of K Na Mg Ca Fe Ammonium	Mineral salts.

---

* Animals contain a trace of carbo-hydrates in the shape of glycogen and glucose.

Preparation.—(1) By heating red oxide of Hg; thus:

$$2\ Hg\ O + heat = 2\ Hg + O_2.$$

(2) By heating black oxide of Mn; thus:

$$3\ Mn\ O_2 + heat = Mn_3\ O_4 + O_2.$$

(3) By heating potassium chlorate; thus:

$$2\ K\ Cl\ O_3 + heat = 2\ K\ Cl + 3O_2.$$

(4) By mixing $K\ Cl\ O_3$ and $Mn\ O_2$ and applying heat, the O is liberated at a much lower temperature from the $K\ Cl\ O_3$, the $Mn\ O_2$ not being affected.

There are many other ways of obtaining O, but these are the best and most common. It can be obtained directly from the air, but not very cheaply.

Physical Properties.—A gas, colorless, odorless, tasteless and invisible; slightly soluble in water; of a specific gravity 1. 1. Like all gases; it can be liquefied.

Chemical properties.—Is incombustible, but supports combustion. F is the only element which does not unite with it. All other elements unite with it to form oxides; thus;

Ba forms $Ba\ O$, barium monoxide.
Mn " $Mn\ O_2$, manganese dioxide.
Fe " $Fe_2\ O_3$, iron sesquioxide.
S " $S\ O_3$, sulphur trioxide.
N " $N_2\ O_4$, nitrogen tetroxide.
P " $P_2\ O_5$, phosphorus pentoxide.

These oxides are of three classes; acid, basic and neutral. Acid oxides are so-called because when united with water they form acids; thus:

$$P_2\ O_5 + 3\ H_2\ O = 2\ H_3\ PO_4,\ \text{phosphoric acid.}$$

Basic oxides are so called because when united with water, they form bases, thus:

$$BaO + H_2O = Ba(OH)_2, \text{ baryta.}$$

Neutral oxides, of which MnO_2 is an example, are so called because they form neither bases nor acids with water.

Function in Nature.—Its chief use is to support combustion. The amount of heat produced by combustion is fixed and depends upon the amount of the substance burned, while the temperature depends upon the rapidity of the combustion. Animal heat and power are derived from combustion, and so O is the chief source of life.

$$\text{Plants eat what animals produce}\left\{\begin{array}{l}CO_2.\\ H_2O.\\ NH_3.\\ \text{Salts.}\end{array}\right.$$

$$\text{Animals eat what plants produce}\left\{\begin{array}{l}\text{Vegetable principles.}\\ O.\end{array}\right.$$

Plants under the action of the sunlight take the CO_2, and split it up into C and O_2, the C then uniting with other elements. In this way they render latent in the C a certain amount of heat, which becomes manifest when united with O. Animals eat the C, and in their tissues it becomes united with O, thus forming again CO_2. The heat developed in this way can then be transformed into force and energy.

OZONE—O_3.

This is a form of condensed O, its specific gravity being one and a half times as heavy as ordinary O, the molecule of which contains but 2 atoms of O.

History.—In 1785, discovered by Von Marum, who called it electrified O. In 1840 Schönbein discovered its nature.

Preparation.—(1) By passing an electric spark through O; thus:

$$3O_2 = 2O_3.$$

(2) By the slow oxidation of P in moist air; thus:

$$2\ P+3O_2=P_2\ O_3+O_3.$$

(3) In the electrolytic decomposition of water, small quantities of O_3 are formed.

(4) By acting upon potassium permanganate with strong sulphuric acid; thus;

$$K_2\ Mn_2\ O_8+3\ H_2\ SO_4=K_2\ SO_4+2\ Mn\ SO_4+3\ H_2O+O_2+O_3.$$

Occurrence.—It is very extensively distributed, in the air, most natural waters, in the juices of plants, etc., but only in very small traces. It is more abundant after thunderstorms. It is formed during slow oxidation, especially of turpentine, and hence is more abundant in pine forests.

Test.—It liberates I from potassium iodide; thus:

$$6\ K\ I+3\ H_2O+O_3=6I+6\ K\ O\ H.$$

If the I is in contact with starch, it will strike a blue color with it. This test is the one commonly used, but is not good, for nitrous acid and hydrogen dioxide will do the same. A reliable test, but not delicate, is the oxidizing of silver foil; thus:

$$Ag_2+O_3=Ag_2\ O+O_2.$$

Properties.—A gas, with a peculiar, strong odor and marked bleaching properties. It is a deodorizer and a disinfectant. It sometimes acts as an oxidizing agent, as shown above, and sometimes as a reducing agent: thus:

$$Ag_2\ O+O_3=Ag_2+2O_2.$$

HYDROGEN—H.

History.—Discovered by Cavendish in 1766.

Occurrence.—In combination in water and in all vegetable principles; in the air, in ammonia, nitrous, nitric and sulphuric acids, and hydrogen dioxide. It is also found free in the sun, stars, comets, etc. Does not exist free on the earth, but is found free in the pores of some meteorites which have fallen on the earth's surface.

Preparation.—(1) By electrolytic decomposition of water, H going to the negative pole.

(2) By the action of metallic Na on water; thus:

$$2\ H_2\ O+Na_2=Na_2\ O\ H+H_2.$$

(3) By the action of steam on red-hot iron; thus:

$$4\ H_2\ O+3\ Fe=Fe_3\ O_4+4\ H_2.$$

(4) Usually by the action of Zn on dilute sulphuric acid; thus:

$$H_2\ SO_4,\ H_2\ O+Zn=Zn\ SO_4,\ H_2\ O+H_2.$$

Properties.—A gas, colorless, odorless, tasteless and invisible, combustible, but not a supporter of combustion. It burns with a pale-blue flame, forming water, and giving off more heat than any other substance, weight for weight. It is the lightest substance experimented with.

Function in Nature.—Aids in the formation of water and of various animal and vegetable substances.

Uses in the Arts.—Used for the heating and illuminating effects in the form of water-gas and of the oxyhydrogen blowpipe. Water-gas is made by passing steam over red-hot coal; thus:

$$C+2\ H_2\ O=CO_2+2\ H_2.$$

This then passes over more red-hot coal, and reacts thus:

$$CO_2+2\ H_2+C=2\ CO+2\ H_2.$$

This mixture is now collected in receivers and saturated with naphtha vapor, which gives it a high illuminating power. On account of its lightness, H has also been used in balloons, but owing to its great cost and diffusibility has been superseded by coal-gas.

COMPOUNDS.—With O.

$H_2 \dot{O}$. *Water* (see WATER).

$H_2 O_2$, *Hydrogen dioxide* or *peroxide.*

Occurrence.—In the air, rain-water and juices of many plants.

Properties.—A liquid, odorless, with a bitter astringent taste. Like ozone, it sometimes acts as an oxidizing agent, sometimes as a reducing agent. It is a deodorizer and disinfectant, but not very good.

Uses.—As a bleaching agent, disinfectant and antiseptic.

NITROGEN—N.

History.—Discovered in 1772 by Rutherford, who called it mephitic air. Lavoisier called it azote.

Properties.—A gas, colorless, odorless, tasteless, invisible, neither combustible nor supporting combustion ; not poisonous, but incapable of supporting life, soluble in water. but less so than O ; a little lighter than air.

Preparation.—(1) By burning P in the air ; thus :

$$2\ P_2 + \text{air},\ 5\,(4\ N_2 + O_2) = 2\ P_2\ O_5 + 20\ N_2.$$

The P_2O_5 is absorbed by water, leaving the N free.

(2) By heating ammonium nitrite ; thus :

$$NH_4\ NO_2 + \text{heat} = 2\ H_2\ O + N_2.$$

Occurrence.—Constitutes free about four-fifths of the atmosphere. Is also found there in combination, as nitrous and nitric acids and ammonia. Is found in all waters in solution. In animals and vegetables in combination, especially as albumenoids and alkaloids.

Function in Nature.—To dilute the oxygen in the air. It is of great value in its various combinations. It is of great value to plants, but can be obtained by them only from its compounds.

COMPOUNDS.—With H.

NH_3, Ammonia.

A gas, colorless, pungent, irrespirable; very soluble in water, and when in solution alkaline; lighter than air; easily liquefied. Does not saponify fats, but makes an emulsion with them.

Found in the atmosphere, rain-water, soil, sewer-gas, urine, etc. Is universally distributed, but occurs in very small quantities usually. It is produced in nature by the action of bacteria on organic bodies containing N.

Its chief source at present is the ammoniacal liquor of the gas-works.

With O:

N_2O,	Nitrogen	monoxide or nitrous oxide.
N_2O_2,	"	dioxide or nitric oxide.
N_2O_3,	"	trioxide or nitrous anhydride.
N_2O_4,	"	tetroxide.
N_2O_5,	"	pentoxide or nitric anhydride.

The important ones are N_2O, N_2O_3, N_2O_5.

N_2O, Nitrogen Monoxide.

Discovered by Priestley in 1783. A gas, colorless, odorless, with a feebly sweetish taste. Incombustible, but supports combustion well; respirable for a short time.

Is best prepared by heating ammonium nitrate: thus

$$NH_4NO_3+\text{heat}=2H_2O+N_2O.$$

It is extensively used as an anaesthetic in dentistry and minor surgery, having been first utilized for this in 1845.

N_2O_3, Nitrous Anhydride.

This when united with water forms nitrous acid, HNO_2:

$$N_2O_3+H_2O=2\ HNO_2.$$

This gives rise to the nitrites in combination.

N_2O_5, Nitric Anhydride.

This forms with water nitric acid, HNO_3 : thus

$$N_2O_5+H_2O=2HNO_3.$$

HNO_3, Nitric Acid.

A liquid, colorless, pungent, with a very acid taste, giving off red fumes when heated ; very corrosive. Stains the skin yellow, forming picric acid.

It is prepared by acting on sodium nitrate or potassium nitrate with sulphuric acid : thus

$$Na\ NO_3 \text{ or } KNO_3+H_2SO_4=Na \text{ or } K\ HSO_4+HNO_3.$$

Acts upon metals thus

$$(1)\ 6Ag+2HNO_3=3Ag_2O+N_2O_2+H_2O.$$

Then the oxide is acted upon by more HNO_3 : thus

$$(2)\ 3Ag_2O+6HNO_3=6AgNO_3+3H_2O.$$

As, Sb and Sn are only oxidized by it. Fuming nitric acid or nitroso-nitric acid consists of nitric acid holding in solution some N_2O_3. All nitrates are soluble in water.

CARBON—C.

Occurrence.—Found free and in combination. All the C now existing, except in the shape of CO_2, owes its present form to the action of animals and vegetables. Free, it is now found as the diamond, graphite and anthracite naturally and artificially in charcoal, lamp-black and gas-carbon.

(1)—Diamond. This is pure carbon, probably of vegetable origin. It crystallizes in cubes and octahedra and is very brilliant, owing to its high index of refraction. It is used for rock-drills, rock-saws, cutting glass, ornaments, etc.

(2)—Graphite, also called plumbago and black-lead. Pure carbon, also of vegetable origin. Crystallizes in six-sided plates. Is used for lead pencils, crucibles, stove-polish, and as a conductor of electricity in electrotyping.

(3)—Anthracite. A variety of coal and almost pure C. It results from the luxuriant vegetation which once existed. This was then subjected to an enormous pressure and to a peculiar fermentation, by which the O and other elements have been driven off. Amorphous. Used for fuel.

(4)—Charcoal. This is of two varieties, wood and animal. Both are amorphous. Used for fuel and as an absorbent of gases and coloring matters ; also as a disinfectant.

(5)—Lamp-black. Besides C, this contains some hydrocarbons. Amorphous. Used chiefly in printers' ink.

(6)—Gas-carbon. This is deposited on the sides of the retort during the destructive distillation of coal in the manufacture of coal-gas. It is very hard and amorphous. Used largely in the electric light and in galvanic batteries.

In combination C occurs in the form of CO_2, carbonates and bicarbonates, and all organic substances, whether of vegetable or animal origin.

Properties.—All varieties are insoluble and infusible, but freely combustible, burning to CO_2 in the air. All but the diamond are good conductors of electricity.

COMPOUNDS.—With O.

CO, Carbon Monoxide.

A gas, not occurring native, colorless, with a slight odor, very poisonous. Does not support combustion, but is combustible. Slightly soluble in water.

Prepared by heating oxalic acid with sulphuric acid : thus

$$H_2C_2O_4+H_2SO_4=H_2SO_4, H_2O+CO_2+CO.$$

The CO_2 is then removed by shaking with lime-water. It is also made in the manufacture of water-gas, for which see H, page 7.

CO_2, Carbon Dioxide or *Carbonic Anhydride.*

A gas, colorless, odorless, with slight pungent taste; fairly soluble in water, neither combustible nor supporting combustion.

It occurs free in the air and in many waters; it is formed during fermentation, respiration, combustion, decay and putrefaction. When dissolved in water it is supposed to form carbonic acid, H_2CO_3, although it is doubtful if there is any real chemical union. The carbonates of the metals are numerous, important and abundant.

It is prepared by acting on calcium carbonate with sulphuric acid: thus

$$Ca\,CO_3+H_2SO_4=Ca\,SO_4+H_2O+CO_2.$$

Also by burning any of the forms of C in oxygen.

In Nature it is upon this that the life of all plants depends. Commercially it is only used in making soda-water.

With H.

These are called hydrocarbons and are found in great numbers in the vegetable kingdom. The only ones important to study in this connection are:

CH_4, Methane or *Marsh Gas.*

A gas, colorless, odorless, tasteless. Called fire-damp when occurring in coal mines. Is combustible, and when mixed with sufficient air explodes with violence on ignition.

C_2H_4, Ethene or *Olefiant Gas.*

A gas, colorless, but with a sweetish taste. Is explosive. Prepared by acting on alcohol with sulphuric acid: thus

$$C_2H_5OH+H_2SO_4=H_2SO_4,\ H_2O+C_2H_4.$$

C_2H_2, Acetylene.

May be formed by the direct union of C and H at a high temperature. Colorless, but burns with a bright flame. Has a very disagreeable odor.

Coal Gas.—Consists of luminous and non-luminous gases. The luminous are C_2H_2, C_2H_4 and other higher hydrocarbons. The non-luminous are H, CO, CH_4. Among the impurities are CO_2, N, sulphuretted hydrogen and other sulphur compounds. Ordinary illuminating flames are composed of three zones. An inner non-luminous zone of unburnt volatile gases composed chiefly of C and H. A middle zone of incomplete combustion, luminous by reason of incandescent C. An outer non-luminous zone of complete combustion, the products being chiefly CO_2 and H_2O. The middle zone of course is the only one we see.

With N.

C_2N_2, Cyanogen.

A gas, colorless, poisonous, with a characteristic odor. Combustible, burning with a pink flame.

HCN, Hydro-cyanic or *Prussic Acid.*

A liquid, colorless, volatile, feebly acid, having an odor of bitter almonds. It is very poisonous. Prepared by acting on potassium cyanide with dilute sulphuric acid : thus

$$2KCN+H_2SO_4, H_2O=K_2SO_4, H_2O+2HCN.$$

The officinal *Acidum Hydrocyanicum Dilutum* contains 2 per cent. by weight of the anhydrous acid. Scheele's Prussic acid contains 4 per cent.

CHAPTER II.

CHLORINE—CL.

History.—Discovered in 1774 by Scheele, who called it dephlogisticated marine-acid gas, as he obtained it from hydrochloric acid, then called marine acid.

Properties.—A gas, of a greenish-yellow color, with a peculiar, disagreeable odor ; in large quantities a powerful irritant. Bleaches vegetable colors in the presence of water. Is a powerful disinfectant and deodorizer.

Occurrence.—Never native. Occurs in nature chiefly as sodium chloride. This is the most abundant soluble salt found on the earth ; it is largely present in sea-water and in most mineral springs, universally distributed through the air and in all animals. Cl is also found in the form of other chlorides.

Preparation.—(1) By acting with hydrocloric acid on manganese dioxide : thus

$$MnO_2+4HCl=MnCl_2+2H_2O+Cl_2.$$

(2) By acting with sulphuric acid on manganese dioxide and sodium chloride : thus

$$2NaCl+MnO_2+2H_2SO_4=Na_2SO_4+MnSO_4+2H_2O+Cl_2.$$

Uses.—Free, as a bleaching agent and a disinfectant. Many of its compounds are very important.

Compounds.—With O.

Cl_2O, Chlorine monoxide.
Cl_2O_3, " trioxide.
Cl_2O_4, " tetroxide.

None of them are of any importance.

With O and H.

Acids of Chlorine—HCl, hydrochloric acid.
$HClO$, hypochlorous "
$HClO_2$, chlorous "
$HClO_3$, chloric "
$HClO_4$, per chloric "

The important ones are HCl, $HClO$, $HClO_3$.

HCl, Hydrochloric Acid.

A gas, colorless, pungent, irrespirable. Neither combustible nor supporting combustion. Used commercially in solution in water, one volume of which takes up about 418 volumes of the gas at ordinary temperature.

Prepared by (1) the direct union of H and Cl under the influence of sunlight: thus

$$H_2+Cl_2=2HCl.$$

(2) Acting on sodium chloride with sulphuric acid: thus

$$2NaCl+H_2SO_4=Na_2SO_4+2HCl.$$

HClO, Hypochlorous Acid.

This is of importance chiefly on account of its salts, which are largely used as bleaching agents. Javelle water is a solution of potassium hypochlorite, $KClO$, and Labarraque's solution, which is the officinal *Liquor sodae chloratae*, one of sodium hypochlorite. The officinal *Calx chlorata*, commonly called chloride of lime, or bleaching powder, has the formula $Ca\,Cl_2O$. This is best represented thus

$$Ca\left\{\begin{matrix}Cl\\ClO\end{matrix}\right.$$

This makes it a chemical compound, having partly the characters of the chloride, partly those of the hypochlorite. It is largely used as a bleaching agent and as a disinfectant. As a deodorizer it simply substitutes its own odor, which has no antiseptic properties at all for the objectionable odor. It is very unstable and must be kept hermetically sealed. All these act by giving up their Cl.

$HClO_3$, Chloric Acid.

A liquid, taking fire spontaneously when dropped on paper. All of its compounds with the metals are soluble. Prepared by acting on barium chlorate with sulphuric acid : thus

$$Ba(ClO_3)_2 + H_2SO_4 = BaSO_4 + 2HClO_3.$$

BROMINE—Br.

History.—Discovered by Balard in 1826.

Properties.—A liquid, of a reddish-brown color, volatile, forming a vapor which is pungent and irrespirable and has a characteristic offensive odor. Not very soluble in water, but freely soluble in alcohol and ether. Not as good a bleaching agent as Cl. Is a disinfectant and escharotic.

Occurrence.—Never native. Is found in sea water and many mineral springs in the form of various bromides. Chiefly obtained from the residue of sea-water, left after crystallizing out sodium chloride.

Uses.—Very little as a bleaching agent, disinfectant or escharotic. Used in photography in the form of silver bromide, Ag Br ; in medicine in the form of bromides of Na, K, etc. ; and in the manufacture of coal-tar colors.

Compounds.—Very similar to those of chlorine, but less stable. $HBrO_2$, bromous acid, corresponding to chlorous acid, is unknown, but the other acids have been prepared.

IODINE—I.

History.—Discovered by Courtois in 1812.

Properties.—A solid, black with a metallic lustre. Only slightly soluble in water, but freely soluble in alcohol, ether, or an aqueous solution of an iodide of an alkali metal. Volatile, with a characteristic disagreeable odor. Upon heating gives off beautiful violet-colored vapors. It is a counter-irritant.

Preparation.—Both I and Br can be prepared as Cl is by method (2), substituting potassium iodide, K I, or sodium bromide, Na Br, for the sodium chloride.

Occurrence.—Never native. Is found combined with metals in sea-water and in various mineral springs, and also in nitre beds. Is very extensively distributed, but usually only occurs in very minute quantities. Marine plants take it up from the sea-water, and it is largely obtained from their ashes.

Uses.—Externally it is used in medicine as a counter-irritant. Internally it is used but little when free, but in its compounds, very extensively.

Compounds.—Very similar to those of Cl but even less stable than those of Br. Neither HIO, hydriodous acid, nor HIO_2, iodous acid, have been isolated.

FLUORINE—F.

Properties.—Has never been satisfactorily isolated. It is probably a colored gas. It is peculiar in that it forms no compound with O.

Occurrence.—Never native. Is extensively distributed in its compounds, especially $Ca\ F_2$, calcium fluoride or fluorspar. Occurs in traces in many animals.

COMPOUNDS.—With H.

H F, Hydrofluoric Acid.

A gas, colorless and powerfully corrosive. Dissolves glass, forming a fluoride of silicon with the silica in it; thus

$$SiO_2+4HF=2H_2O+SiF_4.$$

The four elements just described constitute a group, called the Halogen group, from the Greek hals, sea-salt, and genos, makes. They are so called because they form a natural group with Cl, the most important compound of which is sodium chloride, common salt. They have many resemblances and certain differences. F in most of its characters differs considerably from the other three. These three are all colored, they form many compounds very similarly, all their metallic compounds which crystallize form cubes. Cl is a gas, Br a liquid, I a solid. The atomic weight of Br, 80, is nearly the mean of those of Cl, 35.5 and I, 127. Cl is freely soluble in water, Br fairly, and I feebly. In the order of the chemical strength they are arranged thus : Cl, Br, I, F—i. e., each in this arrangement will displace from their compounds the subsequent ones, but F attacks many metals directly with which the others only combine indirectly.

CHAPTER III.

SULPHUR—S.

Properties.—A solid, of a yellow color, dimorphous, with several amorphous modifications. These modifications may be divided into two classes; A—those soluble in carbon disulphide, and B—those insoluble in that.

A—(1)—Yellow opaque rhombic octahedra of nature.

(2) Long transparent needle-shaped prisms. These return to the rhombic octahedra after a few day's exposure.

(3) The variety of lac sulphuris prepared by acting on alkaline polysulphides with a mineral acid.

B—(1) A tenacious amorphous mass, obtained by pouring S heated to 230° C. into cold water.

(2) Another kind of lac sulphuris prepared by acting on a thiosulphate with a dilute mineral acid.

There are several other modifications of which but little is known.

All the varieties are combustible and volatile. S in many of its chemical properties resembles O quite closely.

Occurrence.—Is found native in volcanic regions from which it is chiefly obtained. Is also found in many ores in combination with various metals as sulphides and sulphates. Is also found in many mineral springs, both free and as sulphides, sulphates and even sulphuric acid. Is found in many organic bodies, in all plants and animals.

Preparation.—Nearly all is prepared from native S by distillation; a little from $Fe\ S_2$, iron pyrites.

COMPOUNDS.—With H.

$H_2\ S$, Hydrosulphuric Acid—also called hydrogen sulphide or sulphuretted hydrogen. A gas, colorless, with a characteristic odor of rotten eggs; fairly soluble in water. Produced in

nature during the putrefactive decomposition of all organic bodies containing S. Also found in many mineral springs.

Prepared by acting on iron sulphide with dilute sulphuric acid, thus:

$$Fe\ S + H_2\ SO_4, H_2\ O = H_2\ S + Fe\ SO_4, H_2O.$$

It is used in the laboratory largely as a reagent in the separation of the metals.

With O.

$S\ O_2$, Sulphur Dioxide or *Sulphurous Anhydride.*—This is usually prepared by burning S in the air. It is a gas, colorless, irrespirable, with a characteristic suffocating odor; easily liquefied and then is used for making artificial ice. It is the most practicable and easily managed disinfectant. For this purpose it is usually prepared by burning S in an iron pot set in a tub of water in the room to be disinfected. It is powerful enough for all practicable purposes. It is also used considerably as a bleaching agent for vegetable colors. It bleaches in a different manner from Cl, for that takes up H and liberates O, while SO_2 takes O and liberates H.

When dissolved in water it forms sulphurous acid.

SO_3, Sulphur Trioxide or *Sulphuric Anhydride*—This in itself is of little importance, but when united with water forms sulphuric acid.

With O and H.

Acids of S—$H_2\ SO_2$, Hyposulphurous acid.
$H_2\ SO_3$, Sulphurous acid.
$H_2\ SO_4$, Sulphuric acid.

$H_2\ S_2\ O_3$, Thiosulphuric acid,
$H_2\ S_2\ O_7$, Pyrosulphuric acid.

$H_2\ S_2\ O_6$, Dithionic acid.
$H_2\ S_3\ O_6$, Trithionic acid.
$H_2\ S_4\ O_6$, Tetrathionic acid.
$H_2\ S_5\ O_6$, Pentathionic acid.

The only ones of importance are sulphuric, thiosulphuric and pyrosulphuric.

$H_2 SO_4$, *Sulphuric Acid.*

This occurs in nature uncombined in a few mineral springs, but chiefly in combination with the metals as sulphates.

It is a liquid, heavy, its specific gravity being about 1.85; volatile, very hygroscopic and when mixed with water, evolving considerable heat. It readily attacks organic matter, blackening them. It is one of the most powerful acids known, being able to displace nearly all the other acids from their compounds, especially when aided by heat. Most sulphates are soluble in water but barium sulphate, Ba SO_4, is very insoluble.

It is prepared in the following way: At one end of a long, low leaden chamber, S or iron pyrites. Fe S_2, is burnt. Either of these when burnt forms SO_2 which passes into the chamber in the form of a vapor. At the same time a certain amount of potassum nitrate. KNO_3, is burnt and from this the gas, $N_2 O_3$, is obtained which is also passed into the chamber. There it meets the SO_2 and gives up to that one of its atoms of O, making the SO_2 into SO_3, and reducing itself to N_2O_2. This N_2O_2 immediately takes up another atom of O from the air present in the chamber, forming $N_2 O_3$ again, which again gives up its extra atom of O to more SO_2. In that way a little N_2O_3 will make the transfer of O to a large amount of $S O_2$. Jets of steam are constantly blowing into the chamber and the H_2O in this meets with the SO_3 and forms $H_2 SO_4$ which falls to the floor. This chamber acid, as it is called, is continually drawn off. It is condensed in platinum pans and then is called pan acid. This constitutes the commercial sulphuric acid or oil of vitriol. To get the chemically pure acid it is still further concentrated in glass vessels.

$H_2S_2O_3$, *Thiosulphuric Acid.*—This was formerly called hyposulphurous and its salts are still commonly known as hyposulphites. The graphic formula has a peculiarity showing the relationship between O and S. In it an atom of S replaces the usual atom of O in one of the hydroxyl groups. [See *Graphic Formulæ* under the head of Acids.] The acid itself has never been isolated, but its alkaline salts are of great importance in photography, as they have the property of dissolving out the silver-salts which have not been acted upon by the light and precipitated.

$H_2S_2O_7$, Pyrosulphuric Acid.—This was formerly called Nordhausen or fuming sulphuric acid. It is largely used for dissolving indigo and in the preparation of artificial vegetable colors.

With C.

CS_2, Carbon Disulphide.—A liquid, volatile, heavy, colorless, having a repulsive odor, which, however, may be due to impurities. It is very inflammable and its vapor forms an explosive mixture with O. Used largely as a solvent of S, P, gutta-percha, caoutchouc, etc.

SELENIUM—SE.
AND
TELLURIUM—TE.

These are unimportant elements very closely related to S and often found associated with it. They form acids similar to sulphuric and sulphurous. Te in many respects resembles the metals and seems to be on the border line between them and the non-metals. They occur only in small quantities and are of very little practical value.

SILICON—SI.

Properties.—A solid, existing in three different modifications, one amorphous and two crystalline, in this respect resembling C. They are all insoluble and are only attacked by one acid, hydrofluoric, which converts Si into SiF_4, a gas.

Occurrence.—Next to O, it is the most abundant element in nature. Never native. It is found combined with O as silica in quartz, sand, flint and many minerals. All clays are silicates of Al and many other silicates are found.

COMPOUNDS.—With O.

SiO_2, Silicon dioxide or Silica.—A solid, tasteless, odorless, soluble in water only when freshly prepared, attacked by no acids but hydrofluoric, almost infusible. Found in all granitic rocks, which are composed of quartz, felspar and mica. Quartz is almost pure silica and so are sand and agates, the latter being a colloidal form which is deposited from silicious water in cavities in the rocks. This silicious water is the chief agent in petrifaction. It forms the skeleton of some invertebrate animals, such as diatoms and sponges. It also gives stiffness to the stems of plants. Hydrated it forms the opal. When freshly prepared and combined with water it forms

H_2SiO_3, Silicic Acid.—This is quite unstable and does not keep well, decomposing into water and and silica. It forms silicates, of which the most important are:

(1) Glass; silicates of K, Na, Pb, Ca, one or more, with an excess of Si present.

(2) Soluble glass; silicate of K or Na, with an excess of base present.

(3) Clay and felspar; both silicates of Al, the latter also containing K.

PHOSPHORUS—P.

Properties.—A solid occurring in two modifications.

(1) Yellow phosphorus, soft and flexible, insoluble in water, but soluble in oils, naptha and carbon disulphide. Poisonous, volatile and very inflammable, being set on fire occasionally by the temperature of the body. Fusible, and luminous in the dark. Combines with O at ordinary temperatures.

(2) Red or amorphous phosphorus. Opaque, insoluble in carbon disulphide, infusible, non-luminous and having no tendency to combine with O. At a temperature of 260° C, it

is reconverted into ordinary P, and then behaves like that. It is not poisonous.

Tidy mentions two other modifications, a white opaque variety and a black variety. Neither are of importance.

History.—Discovered in the urine by Brandt in 1669.

Preparation.—From powdered calcined bones by the following steps :

(*a*) Add sulphuric acid ; thus

$$Ca_3(PO_4)_2+2H_2SO_4=2CaSO_4+CaH_4(PO_4)_2.$$

(*b*) This is then filtered, removing the calcium sulphate, dried and distilled with powdered charcoal ; thus

$$3CaH_4(PO_4)_2+10C=Ca_3(PO_4)_2+6H_2O+10CO+4P.$$

Occurrence.—Very widely diffused, occurring in all rocks, plants, animals and vegetables, but always oxidized. Its chief source at present is the mineral apatite, which is an impure tricalcic orthophosphate, $Ca_3(PO_4)_2$, contaminated with calcium fluoride and calcium chloride. It is not certain how this is formed, but possibly from animal and vegetable remains. In plants and animals, P exists chiefly in the form of this tricalcic orthophosphate. Lecithin is an orthophosphate of an organic base.

Uses.—Free, in the manufacture of matches ; combined, in many ways.

COMPOUNDS.—With H.

PH_3, Phosphorus Trihydride or *Phosphoretted Hydrogen.*—A gas, inflammable, colorless, with a marked alliaceous odor. Resembles in many of its chemical properties ammonia, but is a much weaker alkali.

P forms several other compounds with H, but they are of no importance.

With O.

P_2O_3, Phosphorus Trioxide or *Phosphorous Anhydride.*—A powder, volatile, white. Formed by the slow combustion

of P in a limited amount of air. When combined with water it forms phosphorous acid.

P_2O_5, Phosphorus Pentoxide or *Phosphoric Anhydride.*— A soft, white powder, very deliquescent. Formed by rapid combustion of P in an excess of air.

With O and H.

Acids of P—H_3PO_2, Hypophosphorous acid.
H_3PO_3, Phosphorous "
H_3PO_4, Ortho phosphoric "
$H\ PO_3$, Meta-phosphoric "
$H_4P_2O_7$, Pyro-phosphoric "

The important ones are the last three, which are all derived from phosphoric anhydride ; thus

(1) $P_2O_5+H_2O=2HPO_3$, meta-phosphoric acid.
(2) $P_2O_5+2H_2O=H_4P_2O_7$, pyro phosphoric acid.
(3) $P_2O_5+3H_2O=2H_3PO_4$, ortho-phosphoric acid.

The ortho-acid is the most important, and when the term phosphoric acid is used that is the one usually referred to. It is a liquid, the other two being solid. The meta-acid is known in the Pharmacopeia as glacial phosphoric acid.

BORON—B.

Important only in its combinations. Never native. Occurs as boracic acid, H_3BO_3, in lakes in Tuscany, and as borax, sodium biborate, $Na_2B_4O_7$, in lakes in California and Thibet.

CHAPTER IV.

WATER.

Occurrence.—In the liquid form it occurs in the ocean, seas, lakes, rivers, rain, etc., and is also disseminated throughout the earth's crust. In the solid state, it occurs as snow, ice, glacier, etc. In the state of vapor it occurs as clouds, fog, mist, etc., and is always present in the atmosphere. It occurs as water of crystallization in many minerals. It occurs in all plants and in all animals, constituting about three-fourths of an average man's weight.

History.—In 1781 Cavendish and Watts proved its composition by synthesis. In 1805 Humboldt and Gay-Lussac determined the ratio of its constituents.

Formation.—Formed whenever H or combustible bodies containing H are burnt in O, atmospheric air, or any substance capable of supplying O. This combustion may be rapid or slow, in the air or in animals or elsewhere.

CLASSIFICATION OF NATURAL WATERS.

- Atmospheric
  - rain
  - snow
  - hail, etc.
- Terrestrial
  - A—Sweet—
    - (1) Spring-water
    - (2) Ground-water
    - (3) Well-water
      - open
      - driven
      - artesian
    - (4) Pond or lake-water
    - (5) River-water
  - B—Salt—
    - (1) Ocean-water
    - (2) Inland sea-water

C—Mineral—(1) Sulphur
(2) Saline
(3) Acidulous
(4) Chalybeate
(5) Alkaline
(6) Acid
(7) Alum
(8) Silicious
(9) Borax

ATMOSPHERIC WATERS.

Constituents.—Even rain-water is not pure. It contains :

(1)—Solid particles of dust.

(2)—Germs of animals and plants, including bacteria.

(3)—O, N, carbon dioxide and ammonia, from the atmosphere, of which they are constant components.

(4)—Nitric and nitrous acids are commonly present, chiefly in combination with ammonia.

(5)—Organic substance in small amount.

(6)—Sulphuric acid is nearly always present in rain falling in towns. It comes from sulphur compounds, the products of the combustion of coal.

(7)—Sometimes a very small amount of hydrochloric acid, sodium chloride, calcium chloride and other saline substances.

(8)—Traces of ozone and hydrogen peroxide.

SPRING-WATER.

Constituents.—Always impure. It contains the soluble materials of the soil and these depend upon the nature of the soil through which it passes. When the soil is scanty and the rocks granitic, spring-water is very nearly pure. In other regions, especially in lime stone countries, it is heavily charged with salines. It is generally very clear, sparkling and cool, and on account of these properties very potable. It contains :

(1)—Chlorides, sulphates and bicarbonates of K, Na, Ca and Mg.

(2)—Almost invariably silica in small amounts.

(3)—Usually Al and Fe in traces.

(4)—O, N, ozone and hydrogen peroxide in solution derived from the atmosphere through which it first passed. More O than N is dissolved proportionately. One hundred volumes of the air obtained from water consist of thirty-five of O and sixty-five of N.

(5)—Organic matters of various kinds, derived from the decomposition of plants and animals, chiefly the former. These may be nitrogenous or non-nitrogenous.

(6)—Bacteria and their germs, usually harmless.

Hardness is more apt to occur in spring-waters than others and is due to the lime-salts chiefly, but to some extent to Mg and Fe, found in these waters. The term is used because these elements form insoluble compounds with soaps and in that way prevent the formation of a lather until they are entirely precipitated. The hardness is called temporary when due to the bicarbonates, for by boiling these are converted into carbonates which precipitate. Permanent hardness is due to the sulphates, for these are not affected by boiling. The temporary hardness can be removed as regards boiler-incrustations by the addition of ammonium chloride, for that converts the bicarbonates into freely soluble chlorides, which are not precipitated on boiling. They can also be prevented from forming boiler-incrustations by the addition of starchy or saccharine bodies or some substance like saw-dust, around which they can collect. Temporary hardness may also be removed by the addition of lime, CaO, for this reduces the bicarbonate to the carbonate which precipitates: thus

$$CaH_2(CO_3)_2+CaO=2CaCO_3+H_2O.$$

This is called Clark's process.

GROUND-WATER.

This is the water which is contained in the soil down to the level of the uppermost impervious stratum. It consists of surface-drainage, and for the constituents of it see under "Well-water."

WELL-WATER.

Ordinary open wells are supplied partly by springs and partly by surface-drainage. The constituents which it receives from the former are those naturally present in all sweet waters and are given under "Spring-water." From the latter source it receives:

(1)—Sodium chloride. This is much increased from the drainage of house-refuse.

(2)—Ammonia, nitrates and nitrites. Are generally present, owing to the decomposition of organic matter. They are harmless in themselves, but may be indicative of their source from animals.

(3)—Filtered sewage-matters from the proximity of cess-pools and privies.

(4)—When near grave-yards it is often impregnated with animal matter from recently filled graves.

(5)—At times noxious bacteria.

Driven wells are also partly supplied by surface drainage and nearly to the same extent as open wells. Deep artesian wells which bring water from deep-lying strata supplied from a distance are usuall free from all the organic impurities of well water, though they may contain so much mineral matter as to render them unfit for ordinary purposes. They are serviceable when there is a bed of sand or something permeable to water encased between two layers of clay or rock impervious to water. The slope of the layers must be such that the place where the artesian well is, which goes down into the pervious stratum, must be lower than the point where the water is first collected in the soil. They are not successful in New York City, as the strata do not have that direction, but are almost vertical.

POND, LAKE AND RIVER WATERS.

These are generally purer than spring-water. Rivers are more likely to be charged with suspended impurities, but when the water flows into lakes, the sediment subsides and it becomes clear. Rivers flowing through populous districts often become contaminated with sewage to such an extent as to make them positively offensive and dangerous to those who drink the water. These animal matters, however, soon become oxidized, and thus rendered harmless, by the O held in solution and by the action of the vegetable organisms present, including bacteria. This action renders the water pure within 10 to 12 miles of the source of contamination if the river is of any size. This is true of all waters that are exposed to the air, but especially of those that are in motion.*

SALT WATER.

The water of the ocean contains considerable sodium chloride and magnesium chloride, some potassium sulphate, calcium sulphate, magnesium sulphate, sodium bromide and traces of a number of other elements. The total amounts to 2,138 grains per gallon, of which about four-fifths is sodium chloride. The Dead Sea contains about six times as much mineral matter to the gallon, and the Great Salt Lake about seven times as much. Both of them contain a number of salts, not found in the ocean, and due to the peculiar nature of the soil drained by them.

MINERAL WATERS.

These are natural waters which contain unusually large quantities of some of the ordinary impurities or are characterized by unusual constituents. They may be divided into nine classes, as follows :

---

* This action is much disputed by excellent authorities, who maintain that while it oxidizes the dead organic matter, it has no effect but that of dilution on the living bacteria, especially those of typhoid fever. The Committee of the American Public Health Association on Water Supply endorse the opinion of the English sanitary authorities, viz.: "Of all the processes which have been proposed for the purification of water or of water polluted by excrementitious matters, there is not one which is sufficiently effective to warrant the use, for dietetic purposes, of water which has been so contaminated. In our own opinion, therefore, rivers which have received sewage, even if that sewage has been purified before its discharge, are not safe sources of potable water."

(1)—*Sulphur;* contains sulphuretted hydrogen and the metallic sulphides which give the water its characteristic taste and smell. In addition they usually contain sulphates, carbonates, chlorides and sometimes free S. Examples are Harrowgate of Eng., White Sulphur of Va.

(2)—*Saline* ; those having a salty taste ; of three classes.

1—Brines, containing sodium chloride, as at Syracuse, N. Y.

2—Bitter waters containing magnesium and calcium chlorides, as St. Catherine's Well, Canada.

3—Purgative waters, containing magnesium sulphate or sodium sulphate, as Epsom or Kissingen.

(3)—*Acidulous* ; those containing free carbonic acid in such quantities as to cause effervescence. They generally contain also sodium chloride and bi-carbonatcs of Na, K, Mg, Ca, and Fe besides small amounts of other salts. Examples are Apollinaris, Seltzer, etc.

(4)—*Chalybeate ;* those containing sufficient iron to give them medicinal value on account of it. It is usually in the form of the bi-carbonate or the sulphate. Almost all acidulous waters contain a little Fe. Examples are Sweet Chalybeate Spring, Va.; Cooper's Well, Miss.

(5)—*Alkaline ;* these are not alkaline in the fresh state, but after boiling, owing to the bi-carbonates being converted into carbonates. Besides these they usually contain sodium chloride and traces of other salts. They are usually acidulous too. Examples are the Saratoga waters and the Vichy waters.

(6)—*Acid ;* those containing free mineral acids, such as hydrochloric or sulphuric. Rio Vinaigre, in South America, contains both. Oak Orchard Spring, N. Y., contains free sulphuric acid.

(7)—*Alum ;* those containing alum. In addition they frequently contain free sulphuric acid and Fe in combination. Examples are Rockbridge Alum Spring and Church Hill Alum Spring, both in Va.

(8)—*Silicious ;* those containing a decided amount of silica. They are usually hot springs and contain the alkaline carbonates. The silica is often deposited around the spring in the form of tufa, as the water cools. Examples are the Geysers in Iceland and California.

(9)—*Borax ;* those containing sufficient borax to make it profitable to extract it Examples are certain lakes in Thibet and Cal.

Many mineral waters also contain As and some in sufficient quantities to render them of medicinal value on account of it. Artificial mineral waters if well made are about as good as natural. Comparatively pure spring waters are often fraudulently advertised and sold as mineral waters. Among these are the so-called magnetic springs. These consist of a long iron pipe driven into the earth and furnishing water. The pipe under the action of the earth's magnetism after a time becomes magnetic. It communicates no virtues to the water.

SOURCES AND EFFECTS OF IMPURITIES IN WATER.

Mineral Impurities.—These are derived from the soil. About ten or twenty grains per gallon of the salts of Mg and Ca are necessary for the best interests of health. When more than this is present, however, they are liable to cause dyspepsia, goître and cretinism.

Organic Matter.—This may be derived from vegetation growing on and within the soil. If so, it is harmless and unobjectionable, even though it gives a yellow appearance to the water. It may be derived from the decomposition of animal matter and in that case it may come from cess-pools, privies, manure-heaps, barn-yards, grave-yards, bodies lying on the surface of the ground or in the water, defective and leaky drains, etc. It may be highly dangerous even when present in minute quantities from the bacteria which it may represent. If due to animal decomposition it is accompanied by the presence of nitrates, nitrites, ammonia and usually a considerable amount of sodium chloride, but it is not noxious on account of these. It has caused dysentery, diarrhœa, typhoid fever and cholera through the pathogenic bacteria which it may contain.

Refuse of Factories.—This is unimportant if it runs into a flowing stream. The poisonous salts often neutralize each other and are so rapidly diluted that they become innocuous.

Metallic Impregnations.—These are derived from pipes and tanks. Copper has been occasionally detected in the water and known to give rise to sickness. The most common metal found in water is lead which causes chronic plumbism. One-hundredth grain of Pb per gal. has been known to produce plumbism if taken habitually. If the water contains free O or free carbonic acid or nitrates, it will dissolve considerable Pb. owing to the formation of the hydrate, bi-carbonate or nitrate. If, however, it contains sulphates, these soon form an insoluble film of lead sulphate which prevents further action. Water which has been allowed to stay over night in the pipes should never be used for drinking purposes. Tin-lined lead pipes should always be used in preference to plain lead. They have all the advantages of the lead-pipes and no disadvantages.

DETECTION OF IMPURITIES IN WATER.

(1)—Notice the *taste*, *odor*, *reaction*, *turbidity* and *color*. Pure water should be negative in all these respects.

(2)—*Dissolved Solids.*—Evaporate a given amount of the filtered water, dry the residue and weigh.

(3)—*Organic and Volatile Matters.*—Expose the residue thus obtained to the flame of a Bunsen burner. If organic matter is present, it will turn brown or black. All organic and volatile matters are dissipated. Their weight can be determined by subtracting the weight of the residue left from the weight of the residue left in (2).

(4)—*Hardness.*—This is determined by Clark's test. This consists in using a standard solution of soap to make a lather with the water. The solution is added slowly to the water in a bottle, and each time the bottle is well shaken until finally a lather is made which will remain for five minutes. The soap solution is first standardized by means of a known solution of calcium chloride.

(5)—*Chlorine.*—By means of silver nitrate, Ag NO_3. A known solution is put, drop by drop, into the suspected water in which a few grains of potassium chromate have been dissolved. When all the chlorides have been precipitated as silver chloride, the silver nitrate strikes with the potassum chromate a permanent red color. The silver chloride is a heavy white powder, insoluble in nitric acid but soluble in ammonium hydrate, and blackening on exposure to light. These characters are sufficient to distinguish it from the other two white chlorides which are also insoluble in water, those of Pb and Hg.

(6)—*Sulphuric Acid.*—Acidulate with hydrochloric acid, heat and add barium chloride, Ba Cl_2. It forms a dense white precipate of barium sulphate, Ba SO_4.

(7)—*Nitrous Acid.*—Add sodium sulfanilate and sulphuric acid. Then the addition of naphthylamine sulphate will develop a pink color.

(8)—*Nitric Acid.*—Both this and nitrous acid are reduced to the form of ammonia by means of Zn coated with Cu. This really constitues an electric couple. The amount of ammonia is then determined by Nesslerizing, (see (9)). From this is subtracted the amount of free ammonia as determined by (9) and also the amount due to the nitrous acid as determined by (7). The remainder is that due to the nitric acid.

(9)—*Ammonia.*—By the Nessler re-agent, which is a solution of potassium iodide, KI, and mercuric chloride, Hg Cl_2, in an excess of liquor potassae. This re-agent strikes with ammonia a color, varying from a yellowish to a deep-brown tint, according to the amount of ammonia present. The amount of ammonia is determined by comparing this tint with the color developed in a known solution of ammonium chloride, NH_4Cl, by the same re-agent. The strength of the known solution is varied until it strikes the same color as that of the water. The known solution and the water must then contain the same amount of ammonia.

The ammonia present is of two varieties, free ammonia, which exists free or in loose chemical combination with acids in the water; and albumenoid ammonia, which is not in the form of ammonia, but exists as the N of organic compounds there present. The free ammonia is obtained by simply distilling the water, first having added a stronger alkali, such as soda or potassa. The distillation is continued until no more ammonia comes over. The distillate is then Nesslerized. To the water left in the still some potassium permaganate, $K_2Mn_2O_8$, is added. It is then distilled and by the action of these salts on the albumenoids during boiling they are broken up and the N contained in them is reduced to ammonia. This distills over and is Nesslerized. A good water never contains more than eight parts of free ammonia or fifteen parts of albumenoid ammonia per 1,000,000.

(10)—*Organic Matter.*—By potassium permanganate, $K_2Mn_2O_8$, from which the organic matter takes O: thus

$$K_2Mn_2O_8+3H_2SO_4-5O=K_2SO_4+2MnSO_4+3H_2O.$$

The potassium permanganate is in this way destroyed and the color of the solution, a deep purple, weakened or removed.

(11)—*Calcium.*—Add ammonium chloride and liquor ammoniæ. Then ammonium oxalate, $(NH_4)_2C_2O_4$, gives a white precipitate of calcium oxalate, CaC_2O_4.

(12)—*Magnesium.*—Add ammonium chloride and liquor ammoniæ. Then disodic orthophosphate, Na_2HPO_4, gives a white precipitate of ammonio-magnesian phosphate, $MgNH_4PO_4$. Under the microscope this appears as long, prismatic crystals.

(13)—*Carbon Dioxide.*—The addition of lime-water, which contains calcium hydrate, $Ca(OH)_2$, gives a white precipitate of calcium carbonate, $Ca\ CO_3$. Baryta-water, containing barium hydrate, $Ba(OH)_2$, is often used instead of lime-water, as the barium carbonate formed is even less soluble than the calcium carbonate.

(14)—The sediment should be examined microscopically. This is not of great value, but it may give some idea of the organized life present in the water.

(15)—*Biological Analysis.*—This is to determine the number and kinds of bacteria present in water. Mix 1 c. c. of the water with 10 c. c. of sterilized, gelatinized beef tea which has been melted with a gentle heat. Shake the mixture thoroughly in a sterilized tube and then pour it onto a level sterilized plate. This is set over a cake of ice and over it is placed a glass cover. When it has set it is transferred to an incubator. Great care must be taken during the maipulations that bacteria floating in the air do not get on it. In a few days each bacterium will develop a colony and these can then be counted with the naked eye or with a low-power microscope. The kinds are determined by the microscopical appearance of the bacteria, the appearance and manner of the development of the colonies, the presence or absence of pigment, and in some cases the effect of inoculation on animals.

The results of this method of water-analysis are hardly better than chemical analysis, as yet, but the field is a promising one and further researches may prove its value.

The results obtained by the analysis of water afford at the best but approximate indications for action. It can tell us if the water is absolutely pure, but if impure, it cannot say whether it is dangerous for use or not. If an open or driven well is within one hundred feet of a privy, cess-pool, manure-heap, barn-yard or any source of animal contamination, it should be condemned unless the water is absolutely free from all evidences of organic contamination. Even then it should be examined at short intervals, for either drought or increased rain-fall may cause it to become contaminated. The indications obtained from water-analysis which are of value may be summed up as follows:

(1)—If it contains considerable sediment but no ammonia, nitrites or chlorides, the water is fit for use but the well requires cleaning.

(2)—If there is less than the permissible ammonia and very little or no nitrates, nitrites or chlorides, the water is probably good and the ammonia is either derived from rain-water or is of vegetable origin.

(3)—If the water is hard and contains considerable chlorides but little or no ammonia, nitrates or nitrites, it is good except for the hardness. and the chlorides are derived from the rocks through which it has passed or from the sea-water.

(4)—If it is soft and contains considerable chlorides, it is very suspicious, even though it contains little ammonia, nitrites or nitrates. The chlorides in this case are probably derived from sewage or house refuse.

(5)—If it contains considerable nitrites and chlorides, that would be almost enough to condemn it, even if there is very little ammonia present.

(6)—If it contains an excess of ammonia, chlorides and nitrites, it should be condemned of course.

(7)—If it contains more than the permissible amount of ammonia but no nitrites or nitrates and only traces of chlorides, it is very suspicious. The well should be very carefully examined and unless all possibility of animal contamination is eliminated it should be condemned.

CHAPTER V.

AIR.

THE ATMOSPHERE.

Height.—Shades off insensibly; about one-half is contained within three miles and thirty-one thirty-seconds within seventeen miles.

Weight.—One hundred cubic inches of air weigh thirty-one grains. This is determined by exhausting a vessel of known capacity, finding its weight, then weighing it filled with air and noting the difference. The weight of the atmosphere as a whole, or the pressure of the atmosphere, is approximately fifteen pounds to the square inch. It is determined by means of the barometer.

Composition of the Atmosphere.

A—Gases.

(1)—N_2; by weight 77 parts, by volume 79.
(2)—O_2; " " 23 " " 21.
These figures are only approximate and are determined after removing everything else from the air.
(3)—Water in the form of vapor.—The amount depends largely upon the temperature and varies from 0.1 per cent. to 2 per cent. by weight. When the air contains all the moisture it is capable of taking up at that temperature, it is said to be saturated.
(4)—Carbon Dioxide: by weight 0.06 per cent., by volume 0.04 per cent. There are 63 grains of carbon dioxide on each square inch of the earth's surface.
(5)—Ammonia, 1 part per 1,000,000.
(6)—Nitrous and nitric acids, often in combination with ammonia.

(7)—Ozone and hydrogen peroxide in mere traces.
(8)—Sulphuric acid and other sulphur compounds in the neighborhood of cities, owing to impurities in coal.

B—Solids.

(1)—Cosmical—Meteorites, etc.
(2)—Terrestrial.
  (a)—Mineral—Volcanic dust, fine sand, clay, etc. From the sea-water various mineral salts. Sodium chloride is always present in the atmosphere.
  (b)—Organic.
    1—Dead.—Fragments of plants and animals, hairs, epithelial scales, manure, etc,
    2—Living—Moulds, yeasts and bacteria, and their germs, and pollen.

Of these constituents of the atmosphere, those which are especially related to plants are carbon dioxide, water, ammonia, nitric and nitrous acids. These form the food of plants. All the C in plants is obtained from carbon dioxide, the O being returned to the atmosphere. They obtain all their N from these compounds, none being taken from the free N of the atmosphere. In the plants these compounds are split up and reunited into others which are but slightly oxidized. Plants also have a respiratory function by which they consume O and give off carbon dioxide. This is of very much less importance than their consumption of carbon dioxide and is best noticed in the absence of light when that function is in abeyance.

Those constituents which are especially related to animals, are water and O. Most other components of animals are derived from plants and are oxidized by the O taken from the atmosphere.

Of the other components of the atmosphere, not much need be said. The N is simply a diluent of the O, and the others are accidental impurities. Moulds and their germs cause the formation of moulds ; yeasts and some bacteria cause fermentations ; other bacteria cause putrefaction ; and some varieties of pollen cause hay-fever. The suspended mineral and dead organic matter, if present in excess, may act as an irritant to the lungs, and cause a variety of interstitial pneumonia.

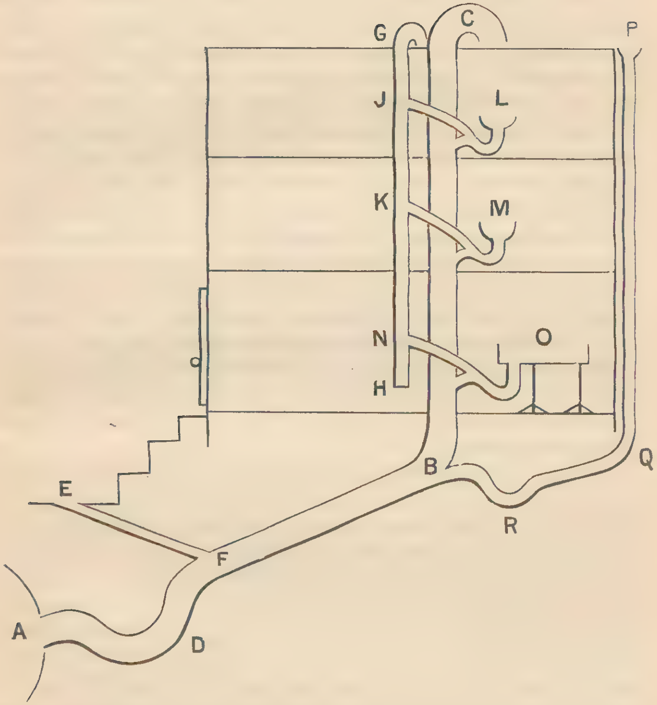
HOUSE-DRAINAGE.

This should be so constructed as to keep out of the air of the house any admixture of sewer-gas, but it often fails entirely owing either to incorrect or defective plumbing. The composition of sewer gas is approximately as follows:

(1)—Methane and carbon dioxide chiefly.
(2)—H, N, and ammonia.
(3)—Acetic, lactic and butyric acids.
(4)—Sulphuretted hydrogen, mercaptans and sulphur ethers which give it the offensive odor it may possess.

None of these are given off in such quantities under ordinary circumstances as to produce disease themselves. The danger is from the pathogenic bacteria which may be present. These are not volatile but are sprayed up into the air of the sewer by the breaking of bubbles on the surface. Their specific gravity is then so light that they are carried by the air-currents. The way to prevent disease from this source is by proper plumbing. To do this the soil-pipe and back-air-pipe should open on the roof, and every trap should be back-aired. The accompanying diagram shows these pionts:

A is the sewer. ABC is the soil-pipe, opening on the roof at C and trapped at D. EF is the ventilating-pipe communicating with the soil-pipe just behind D. GJKH is the ventilating-pipe to the traps, opening on the roof at G and giving off branches at J, K and N to the traps of the fixtures L, M, O, which branches are connected on the soil-pipe side of the traps as indicated. PR is the leader from the roof connecting with the soil-pipe at B and trapped at R. The object of EF is to have a constant current of air blowing through the pipe. The air in BC, being within the house, becomes heated and escapes through C, while fresh air enters through EF. The object of GH and its branches, J, K, N, is to prevent siphoning of the traps by an action similar to that of the Sprengel air-pump.



[The engraver has made all the traps in the diagram too shallow, except at R. They should be so deep as to divide the U-shaped column of water into two distinct limbs, connected only at the bottom.]

Besides the points indicated in the diagram and its explanation, there are some others in practical plumbing which it is well to bear in mind. The soil-pipe should be of iron and 4 inches in diameter. After it changes from the perpendicular it should have such a slope as to insure a current of at least 4½ ft. per second. The traps should be the S-shaped syphon traps and preferably those without pans or hoppers but flushing directly. The water-closets should not communicate directly with the house-tank but with small waste-preventer tanks, containing 2-4 gals., which are filled automatically from the house-tank. The over-flow pipes if they empty into the house-drain, should do so on the side of the trap furthest from the drain. The sewer should be of an oval egg-shape with the small end down. It should be smooth internally and have a slope sufficient to cause a current of not more than 4½ ft. per second nor less than 1 ft. It should have ventilating shafts and man-holes at intervals of not more than 100 yards. The best method of sewage-removal undoubtedly is the separate system. In this there are two sets of pipes ; one set is small and securely sealed for the removal of the house-refuse ; the other is larger and serves to carry away the surface and subsoil drainage.

Ground-air is that which fills in the interstices of the ground down to the water level. It is derived largely from the decomposition of vegetable and animal remains in the soil. It is detrimental to health from the large amount of moisture always present and from the pathogenic bacteria which it may contain. In order to keep it out of the cellar, Prof. Chandler recommends that coal-tar pitch be used in the following way : Melted hard coal-tar pitch is poured on the floor in a thin layer and on this, while still soft, bricks are placed close together on edge. When the whole is set more melted pitch is poured over it, sufficient to fill up the spaces between the bricks and cover the whole to the depth of a quarter-inch. The sides of the cellar are then covered with the pitch up to the level of the ground.

VENTILATION.

In the previous section were discussed the methods of keeping impure air out. In order to let fresh air in and to remove the air rendered impure within the house, thorough ventilation is necessary. The percentage of carbon dioxide in the atmosphere of a room vitiated by respiration should never exceed .06 per cent. by volume. This is taken as the limit, not, however, because that amount of carbon dioxide is injurious. Pettenkofer and Voit found that it produced no injurious effects in the amount of 1. per cent., but that was when it was not due to respiration. In the air of a room it is taken as representing the volatile organic matters, which are in such small quantities that they cannot be measured directly, but which are very injurious to the health. Taking .06 per cent. as the limit, each human adult requires about 3,000 cubic feet of air per hour. In order to supply this amount the air-space to each adult should be not less than 1,000 cubic feet, for it is found that the air in a room cannot be changed by most methods of ventilation oftener than three times per hour without creating draughts.

Methods of ventilation may be divided into natural and artificial. Natural methods depend for their action on :

(1)—Diffusion. Of very little consequence as a ventilating force.

(2)—Difference in density between warm and cold air, the warm rising and the cold forcing its way in.

(3)—Of most importance, the perflating and aspirating action of the wind. The former is utilized in cross-ventilation between windows or perforations in walls. Draughts should be avoided, and in order to do so, many ingenious devices have been used. A very simple one is to raise the lower sash of a window a few inches and insert under it a block of wood just fitting the aperture. In that way a space is left between the upper and lower sashes by which the breeze is directed up towards the ceiling. Screens can be used, but they easily become clogged with dust. To utilize the perflating force, movable cowls are put on air-shafts, which communicate with the room.

Methods for artificial ventilation are of two kinds, those acting by extraction and those by propulsion. The former is by all odds the most efficient, stable and economical. In it the extraction force of heat, either by fires or special flues, is used. Fans and screws have been used in this as well as in the propulsion system. They are not considered of much use.

The sources of pollution of the atmosphere are numerous. The following are the more important:

(1)—Factories, especially those for oil, fertilizers, glue and gas.
(2)—Putrefaction and decomposition of animal and vegetable matter.
(3)—Ground-air.
(4)—Respiration of animals.
(5)—Combustion in lamps, stoves and of gas. In addition to water and carbon dioxide, this gives rise to some sulphur compounds. In the case of stoves, if the damper is turned so as to stop the draught while the combustion is still going on, the products of combustion must escape into the room. Unless there is sufficient ventilation they may cause considerable harm.

CHAPTER VI.

CHEMICAL NOMENCLATURE.

It has been thought advisable to give the substance of the preceding chapters before discussing the definitions and terminology used. It is better, for concise definitions in Chemistry are difficult or impossible. In this way the student is enabled to appreciate the exceptions which naturally arise.

Base.—The term properly applied to the combination of a basic oxide with water; thus $K_2O+H_2O=2KOH$, called potassium hydroxide or hydrate, or potassa; or $CaO+H_2O=Ca(OH)_2$, called calcium hydroxide or hydrate, or lime. The term is sometimes used to mean simply the basic oxide, but this is not correct.

Anhydride.—This is simply another name for an acid oxide; thus P_2O_5, phosphoric oxide or anhydride.

Acid.—Hard to define concisely. It is a salt of H. It can be produced by combining water with an anhydride; thus $H_2O+N_2O_5=2HNO_3$, nitric acid. In the case of S, Se, Te, Cl, Br. I and F, the direct combination of the element with H forms an acid, thus H_2S, hydrosulphuric acid, HCl, hydrochloric acid.

Salt.—Also hard to define. It is the term applied to a combination of an anhydride with a basic oxide; thus $CaO+CO_2=CaCO_3$, calcium carbonate. Also applied to an acid in which the H has been replaced wholly or in part by a metal or by a compound radical having the characters of a metal; thus NH_4Cl, ammonium chloride. If the H has been wholly replaced, it is called a normal salt; if partly, an acid or bi-salt; thus K_2SO_4, normal potassium sulphate or simply potassium sulphate, $KHSO_4$, acid potassium sulphate or potassium bisulphate.

When two oxygen-acids are formed by the same element, the one containing the less proportionate amount of O terminates in *ous*, the other in *ic*; thus $HClO_2$, chlorous acid, and $HClO_3$, chloric acid. The same rule applies to oxides and hydrates if more than one is formed. If there is another oxygen acid of the same element which has less O proportionately than the ous acid, *hypo* is prefixed; thus HClO, hypochlorous acid. If another is present with more O proportionately than the ic acid, *hyper* or *per* is prefixed; thus $HClO_4$, hyperchloric or perchloric acid. Acids not containing O have the prefix *hydro* and terminate in *ic*; thus HBr, hydrobromic acid.

Oxygen-salts, if derived from acids terminating in ous, terminate in *ite;* thus K_2SO_3, potassium sulphite, NaClO, sodium hypochlorite. If they are derived from acids terminating in ic, they terminate in *ate;* thus Na_2CO_3, sodium carbonate, $NaHCO_3$, sodium bicarbonate. Salts derived from acids not containing O drop the hydro and terminate in *ide;* thus Ag_2S argentic or silver sulphide, $MgCl_2$, magnesium chloride. If two salts are formed by the same two radicals, the one containing the less proportionate amount of the non-metallic element is designated by *ous*, the other by *ic;* thus Hg_2I_2, mercurous iodide, HgI_2, mercuric iodide; $Fe(NO_3)_2$, ferrous nitrate, $Fe_2(NO_3)_6$, ferric nitrate.

It will be good practice for the student to run over the following lists and name the compounds or give the formulæ, as the case may be:

H_2SO_2
H_2SO_3
H_2SO_4
HNO_2
HNO_3
KCl
LiClO
$NaClO_2$
As_2O_3
As_2O_5

$KClO_3$
$AgNO_3$
H_3PO_3
H_3PO_4
$FeSO_4$
$Fe_2(SO_4)_3$
$Fe(OH)_2$
$Fe_2(OH)_6$
$MgSO_3$
$CuSO_4$

Na_2SO_4
$NaHSO_4$
Na_3PO_4
Na_2HPO_4
K_2CO_3
$KHCO_3$
$Ca_3(PO_4)_2$
$CaH_4(PO_4)_2$
NH_4HCO_3
$(NH_4)_2CO_3$

NaOH
$CaSO_3$
Hg_2Cl_2
$HgCl_2$
$BiCl_3$
SO_2
SO_3
NH_4NO_2
SiO_2

Hydrochloric acid
Hypochlorous "
Perchloric "
Potassium hydrate
Ferrous "
Ferric "
Magnesic "
Ammonic "
Sodic carbonate
" bicarbonate
" sulphate
" bisulphate

Bismuth Nitrate
Calcic bromide
Sodic Phosphate
" biphosphate
Cupric nitrate
Ferrous chloride
Ferric "
Hydriodic acid
Calcic sulphate

Simple Radical.—A term sometimes applied to an element.

Compound Radical.—A compound in which one or more combining bonds are free. These are of more consequence in Organic than Inorganic Chemistry. They are usually designated by the ending *yl* and may be monad, dyad, triad, etc. They behave like elements as regards their chemical properties. Examples are $(CH_3)^i$, methyl; $(NH_4)^i$, ammonium; $(Sb\ O)^i$, stibyl; $(Bi\ O)^i$, bismuthyl.

Proximate Analysis.—Applied to the analysis of a mixture of several molecules when only the nature of each of the several molecules is determined. The proximate analysis of milk shows it to contain casein, lactose, fats, serum-albumin, etc. Those bodies, the nature of which is determined by proximate analysis, are called proximate principles.

Elementary or *Ultimate Analysis.*—Used when the number and kinds of atoms which compose one of the proximate principles. are determined. The elementary analysis of sugar shows it to be $C_{12}H_{22}O_{11}$.

Empirical Formula.—The expression of the simplest possible ratio of the elements which make up a compound. Thus

CH is the empirical formula for benzol.
$Fe\ (OH)_3$ " " ferric hydrate.

Molecular Formula.—The expression of the actual number of atoms of each element in a molecule. It may be identical with the empirical formula or a multiple of it. Thus

C_6H_6 is the molecular formula for benzol.
$Fe_2(OH)_6$ " " " ferric hydrate.
$C_{12}H_{22}O_{11}$ represents both formulæ for sugar.

Type Formula.—Is a molecular formula arranged after a certain type. The most common types are water, HOH, and hydrochloric acid, HCl. Thus

$HO(C_2H_3O)$, is acetic acid arranged on the water-type,
$H(C_2H_3O_2)$ the same on the hydrochloric acid type.

Isomerism.—The term used when two or more bodies have the same empirical formula but differ in their properties. It is of two varieties.

A—When the bodies have the same number of atoms. This may also be of two varities.

(1)—Isomerism proper. In this the compounds differ only in their physical properties. Thus the volatile oils of lemon, turpentine, juniper, etc., have all the formula, $C_{10}H_{16}$ and differ only in their odors and some other physical properties.

(2)—Metamerism. In this the compounds have the same empirical and molecular formulæ but the atoms composing them are arranged in different ways; thus

$(NH_2)_2CO$ is urea.
NH_4CNO is ammonium cyanate.

B—Polymerism. In this the compounds have the same empirical but different molecular formulæ; thus the various olefines, CH_2, C_2H_4, C_3H_6, etc.

Homologous Series.—A group of substances, having similar properties, whose molecular weights have a common difference. In Inorganic Chemistry the most marked series of this kind is the alkaline metals. These all have a common difference of 16 or of some multiple of 16, and this fact alone would tend to show they were simply compounds. In Organic Chemistry the term is only applied to a series having a common difference of 14, due to CH_2 ; thus CH_4, C_2H_6,C_3H_8, etc.

Isologous Series.—Only used in Organic Chemistry to mean a series whose molecular weights have a common difference of 2, due to H_2 ; thus C_6H_6, C_6H_8, C_6H_{10}, etc.

Allotropic.—A term applied to those modifications of the same substance which present different physical properties. Thus C exists in three allotropic forms, diamond, graphite and charcoal ; O in two, common oxygen and ozone.

Amorphous.—Applied to a solid which is not crystalline.

Dimorphous.—Applied to a solid which crystallizes in two irreconcileable forms ; as C in the diamond and graphite.

Isomorphous. —Applied to substances of different chemical composition, which crystallize in the same form. In Inorganic Chemistry the different alums form a striking group of this kind.

Efflorescent substances are those which at the ordinary temperature lose their water of crystallization and fall to powder : as sodium carbonate.

Deliquescent substances are those freely soluble substances which at ordinary temperatures takes up sufficient water from the air to form a solution. Potassium hydrate and phosphoric anhydride are examples

An *alloy* is a compound or mixture of two or more metals. If one of them is mercury, it is called an *amalgam.*

Atomicity or *Valence.*—The term applied to the combining or saturating power of an element or the number of bonds it possesses. It may be :

Univalent	or	Monad
Bivalent	"	Dyad
Trivalent	"	Triad
Quadrivalent	"	Tetrad

Quintivalent	or	Pentad
Sexvalent	"	Hexad
Septivalent	"	Heptad

And even higher atomicities exist. Artiads are those of even atomicity, perissads of uneven.

Double decomposition is the mutual interchange of components when two substances are brought together. It is most apt to occur when a more volatile or a less soluble substance can be formed by it. Thus

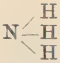
$$2SbCl_3+3H_2S=\overline{6HCL}+\underline{Sb_2S_3}$$

$$Ba(NO_3)_2+H_2SO_4=\underline{BaSO_4}+2HNO_3$$

CHAPTER VII.

GRAPHIC FORMULÆ.

Graphic formulæ are those formulæ which are supposed to represent the internal structure of a molecule. They are intended to show the way in which the atoms of molecules are held together by connecting bonds. In constructing them compound radicals must be very carefully considered. Another thing to be remembered is that an element may change its atomicity, for example, a triad to a pentad or a dyad to a tetrad, but they never change from artiad to perissad, or *vice versa*. They are sometimes made after various types. The most common and most important of these are :

1. The water type, H—O—H
2. The hydrochloric acid type, H—Cl
3. The ammonia type, 
$\mathrm{N}\begin{array}{l} \diagup \mathrm{H} \\ \text{—}\mathrm{H} \\ \diagdown \mathrm{H} \end{array}$

The atomicity of the elements must be very carefully learned. The following is a list of the more important elements, with their symbols, arranged according to their atomicities :

MONADS.

H	Hydrogen	
Ag	Silver	
Cl	Chlorine	Halogens.
Br	Bromine	
Fl	Fluorine	
I	Iodine	
Li	Lithium	Metals of the Alkalies.
K	Potassium	
Na	Sodium	
Cs	Caesium	
Rb	Rubidium	

DYADS.

O	Oxygen	Oxygen Group.
S	Sulphur	
Se	Selenium	
Te	Tellurium	
Ca	Calcium	Metals of the Alkaline earths.
Ba	Barium	
Sr	Strontium	
Mg	Magnesium	Magnesium Group.
Zn	Zinc	
Cd	Cadmium	
Hg	Mercury	Mercury Group.
Cu	Copper	

TRIADS.

B	Boron	
N	Nitrogen	
P	Phosphorus	
Au	Gold	
As	Arsenic	Arsenic Group.
Bi	Bismuth	
Sb	Antimony	

TETRADS.

C	Carbon	
Si	Silicon	
Al	Aluminium	
Pt	Platinum	Platinum Group.
Ir	Iridium	
Os	Osmium	
Rh	Rhodium	
Pd	Palladium	
Ru	Ruthenium	
Fe	Iron	Iron Group, sometimes dyad, sometimes tetrad.
Ni	Nickle	
Co	Cobalt	
Mn	Manganese	
Cr	Chromium	
Sn	Tin	
Pb	Lead	

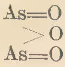
In the graphic formula of a saturated compound, the bonds must be so arranged as to satisfy the atomicity of each of the elements.

OXIDES.

Monads—K, K_2O, K—O—K; may be considered water in which both atoms of hydrogen are replaced by potassium.

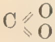
Dyads.—Ca, CaO, Ca=O.

Triads.—As, As_2O_3,



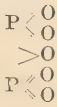
$$\begin{array}{l} As{=}O \\ \quad >O \\ As{=}O \end{array}$$

Tetrads.—C, CO_2,



$$C\begin{array}{l} \diagup\!\!\!\diagup O \\ \diagdown\!\!\!\diagdown O \end{array}$$

Pentads. — P, P_2O_5,

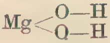


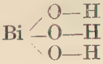
$$\begin{array}{l} P\begin{array}{l} \diagup\!\!\!\diagup O \\ \diagdown\!\!\!\diagdown O \end{array} \\ \quad\;\; >O \\ P\begin{array}{l} \diagup\!\!\!\diagup O \\ \diagdown\!\!\!\diagdown O \end{array} \end{array}$$

BASES.

In these the monad radical, H—O, called hydroxyl, enters. Hence they are called hydroxides. They may also be considered as one or more atoms of water in which one-half the number of hydrogen-atoms are replaced by the element or basic radical. In this case they are called hydrates.

Monads.—Na, NaOH, $Na{-}O{-}H$

Dyads.—Mg, $Mg(OH)_2$,  $Mg<\begin{matrix}O{-}H\\O{-}H\end{matrix}$

Triads.—Bi, $Bi(OH)_3$,  $Bi\begin{matrix}/O{-}H\\-O{-}H\\\backslash O{-}H\end{matrix}$

None of any consequence are formed above triads. The term base is also applied to the basic oxides.

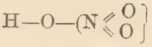
ACIDS.

Those not containing oxygen are formed by the direct union of hydrogen and the element, as H Cl, H—Cl, H_2S, $\begin{matrix}H\\H\end{matrix}>S$. The latter can also be considered water in which the oxygen has been replaced by sulphur, and would then be written thus, H—S—H. In the oxygen-acids or those containing oxygen, hydroxyl plays a very important part. The basicity of an acid is the number of hydrogen-atoms it contains, which are replaceable by metals. In the inorganic acids all the hydrogen-atoms are replaceable with the exception of hyposulphurous acid, H_2SO_2, hypophosphorous acid, H_3PO_2, which are monobasic, and phosphorous acid, H_3PO_3, which is bibasic. An oxygen-acid contains as many hydroxyl-groups as its basicity, and it is the hydrogen-atom in this group which can be replaced by a metal to form a salt. A monobasic acid consists of hydroxyl united by the free bond of the oxygen to a monad element or compound radical which has an acid tendency. It may also be considered water in which one hydrogen-atom has been replaced by this element or compound radical. Polybasic acids are formed in a similar way. The following is a list of the more important acids arranged according to basicity. The element or compound radical with which the hydroxyl is united is enclosed in brackets.

MONOBASIC.

Nitrous, H—O—(N═O)

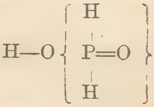
Nitric,



$$H-O-\left(N\begin{matrix}{=}O\\{=}O\end{matrix}\right]$$

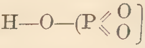
Hydrocyanic, H—(C≡N)

Hypophosphorous,



$$H-O\left\{\begin{matrix}H\\ |\\ P{=}O\\ |\\ H\end{matrix}\right\}$$

Metaphosphoric,



$$H-O-\left(P\begin{matrix}{=}O\\{=}O\end{matrix}\right]$$

Hydrochloric, H—Cl

Hypochlorous, H—O—(Cl)

Chlorous, H—O—(O—Cl)

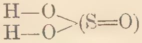
Chloric, H—O—(O—O—Cl)

Perchloric, H—O—(O—O—O—Cl)

Bromine and iodine form acids similar to those of chlorine, but fluorine forms only H F, hydrofluoric acid.

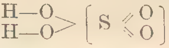
BIBASIC.

Sulphurous,



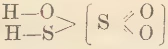
$$\begin{matrix}H-O\\H-O\end{matrix}>(S{=}O)$$

Sulphuric,



$$\begin{matrix}H-O\\H-O\end{matrix}>\left[S\begin{matrix}{=}O\\{=}O\end{matrix}\right]$$

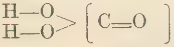
Thiosulphuric,



$$\begin{matrix}H-O\\H-S\end{matrix}>\left[S\begin{matrix}{=}O\\{=}O\end{matrix}\right]$$

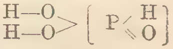
Hydrosulphuric, H—S—H

Carbonic,



$$\begin{matrix}H-O\\H-O\end{matrix}>\left[C{=}O\right]$$

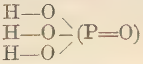
Phosphorous,



$$\begin{matrix}H-O\\H-O\end{matrix}>\left[P\begin{matrix}\diagup H\\{=}O\end{matrix}\right]$$

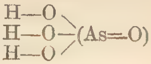
TRIBASIC.

Orthophosphoric,



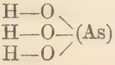
$$\begin{matrix}H-O\diagdown\\H-O-\\H-O\diagup\end{matrix}(P{=}O)$$

Arsenic,



$$\begin{matrix}H-O\diagdown\\H-O-\\H-O\diagup\end{matrix}(As{=}O)$$

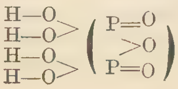
Arsenious,



$$\begin{matrix}H-O\diagdown\\H-O-\\H-O\diagup\end{matrix}(As)$$

TETRABASIC.

Pyrophosphoric,



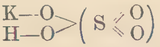
$$\begin{matrix}H-O\\H-O\end{matrix}>\left(\begin{matrix}P{=}O\\>O\\P{=}O\end{matrix}\right)\quad\begin{matrix}H-O\\H-O\end{matrix}>$$

SALTS.

The graphic formulæ for these are easily worked out if the atomicity of the element and the basicity of the acid are remembered for the element is simply substituted for the hydrogen of the acid. In the case of the oxygen-acids, it is only the hydrogen of the hydroxyl group which can be replaced. It is a good plan to write out first the graphic formula of the acid and then to substitute the metal in it, replacing one hydrogen-atom by a monad, two by a dyad, and so on.

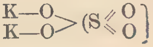
SALTS OF MONADS.

$KHSO_4$,



etc.

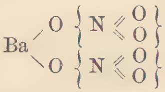
K_2SO_4,



SALTS OF DYADS.

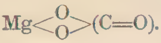
With monobasic acids—

$Ba(NO_3)_2$,

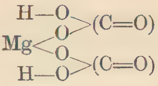


With bibasic acids, two varieties—

$MgCO_3$,

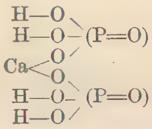


$MgH_2(CO_3)_2$,

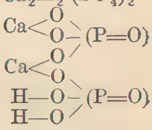


With tribasic acids, 3 varieties—

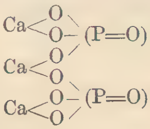
(1) $CaH_4(PO_4)_2$,



(2) $Ca_2H_2(PO_4)_2$

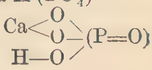


(3) $Ca_3(PO_4)_2$,



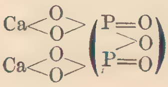
or

$CaH(PO_4)$



With tetrabasic acids—

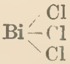
$Ca_2P_2O_7$,



SALTS OF TRIADS.

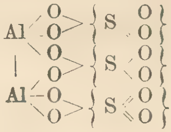
With monobasic acids—

$BiCl_3$,



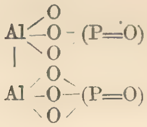
With bibasic acids—

$Al_2(SO_4)_3$,

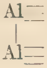


With tribasic acids—

$AlPO_4$,



Aluminium is better regarded as a tetrad, as shown in the diagrams; but it amounts to a triad, as two of the bonds are lost in the double molecule, thus:



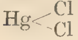
$$\begin{array}{l} Al\equiv \\ | \\ Al\equiv \end{array}$$

SALTS OF MERCURY AND COPPER.

These are always dyad; but in the ous-compounds they form double molecules, in which two of the four bonds are lost, thus:

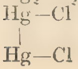
Mercuric chloride,

$HgCl_2$



Mercurous chloride,

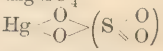
Hg_2Cl_2



$$\begin{array}{l} Hg-Cl \\ | \\ Hg-Cl \end{array}$$

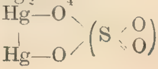
Mercuric sulphate,

$HgSO_4$



Mercurous sulphate,

Hg_2SO_4



SALTS OF THE IRON GROUP.

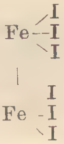
In the ous-compounds these are dyad. In the ic-compounds they are tetrad, but two of the bonds are lost as in the aluminium group.

For the ous-salts, see "Salts of dyads."

For the ic-salts,

With monobasic acids—

$Fe_2 I_6$,

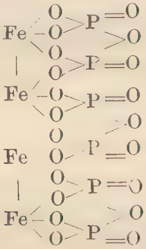


With bibasic and tribasic acids—

See salts of Aluminium under "Salts of triads."

With tetrabasic acids—

Ferric pyrophosphate, $Fe_4 (P_2O_7)_3$,



There still remain a few special salts such as bismuth subcarbonate and subnitrate, borax, etc., which are considered in connection with the metals of which they are compounds.

CHAPTER VIII.

. THE METALS.

There are over fifty metals. The number varies from year to year, for new ones are being discovered and old ones are found out to be only compounds. Very recently it has been announced that nickel and cobalt are simply compounds of one substance just discovered. Only twenty-five are of sufficient importance to be discussed here.

The properties of the metals in general are as follows :

(1)—Metallic lustre. Very characteristic but not absolute, for C and I possess it.
(2)—Good conductors of heat and electricity.
(3)—All solid at ordinary temperatures but Hg.
(4)—All are electropositive, Cs being most marked.
(5)—Color. Except Cu and Au, most of them range from yellowish-white to bluish-white.
(6)—With three exceptions all are heavier than water. The exceptions are, in the order of their lightness, Li, K, Na.
(7)—Nearly all are malleable, Au being the most marked.
(8)—Most of them are ductile.
(9)—Tenacity is fair in most but very slight in some, as Pb.
(10)—Fusibility varies greatly, but all can be melted.
(11)—Volatility is present only in a few, but probably exists in all if we could get sufficieut heat.
(12)—All are markedly insoluble in water.

The classification of the more important metals has been given in the preceding chapter. The first six metals in the order of their frequency are Al, Ca, Mg, Fe, Na, K.

THE ALKALINE METALS.

These are Li, Na, K, Rb and Cs and ammonium is usually discussed with them. They have the following characteristics :

All are monads, of low specific gravity, soft and easily fusible: in contact with water, they decompose it and form hydroxides, which are called alkalies, and from these the water can not be driven off by heat; each forms but one chloride; their carbonates are soluble in water and are alkaline. The properties of an alkali consist in turning red litmus blue and yellow turmeric brown, saponifying fats and neutralizing acids; if at all concentrated it is a local irritant or even caustic. Li, K, Na were discovered by Sir Humphrey Davy in 1807–8, Cs and Rb in 1860–1 by Kirchoff and Bunsen.

The relation of the atomic weights is striking. There is 16 between Li and Na, and between Na and K. There is approximately 3 times 16 between K and Rb and between Rb and Cs. They form an homologous series and are evidently compounds, 2 of the series between K and Rb and 2 between Rb and Cs not having been discovered.

POTASSIUM—K.

Properties.—Bluish-white. Undergoes spontaneous combustion when dropped into water. Burns with a purple flame. Its spectrum consists of a bright line in the red and another in the violet.

Occurrence.—Never native. Very extensively distributed in many rocks, many mineral springs and deposits, in sea-water, in all plants and animals. Its principal sources are:

(1)—Argol or impure cream of tartar, the commercial name for potassium tartrate. This is obtained during the fermentation of grape-juice.

(2)—The mother liquor left after crystallizing out beet-sugar.

(3)—Wool fat, which is composed chiefly of cholesterin, but contains some K.

(4)—Large mineral deposit at Stassfurt, Germany. This is at present the chief source. The principal potassium compound found there is potassium chloride, KCl.

Preparation.—By heating potassium carbonate with C and distilling, thus:

$$K_2CO_3+2C=3CO+K_2.$$

CO escapes as a gas, K distills over and is collected under naphtha. It must be re-distilled since an explosive compound, $K_6C_6O_6$ (?), is formed at first to some extent.

COMPOUNDS.

KI, Potassium Iodide.—A white solid, fusible, very soluble in water, used extensively in medicine. Prepared by mixing I with a solution of potassa, thus

$$6KOH+3I_2=5KI+KIO_3+3H_2O.$$

In order to get rid of the iodate present the whole is evaporated to dryness, mixed with powdered charcoal and heated to redness, thus

$$KIO_3+3C=3CO+KI.$$

It is then filtered and crystallized.

KCl, Potassium Chloride.—Very frequently found in nature. Otherwise not of much importance.

KBr, Potassium Bromide.—Prepared similarly to potassium iodide. Extensively used in medicine.

K_2O, K_2O_2, K_2O_4, K_2O_5, K_6O_4, K_4O_3.—Simply chemical curiosities.

KOH, Potassium Hydrate or Potassa.—Also called caustic potash. It is the strongest alkaline substance known. A powerful escharotic. In water forms a lye, and with fats forms soft soaps. Very deliquescent and easily fusible. May be prepared

(1)—By adding K to water, thus

$$K_2+2H_2O=2KOH+H_2.$$

The H takes fire spontaneously.

(2)—By adding calcium hydrate to potassium carbonate, thus

$$Ca(OH)_2+K_2CO_3=CaCO_3+2KOH.$$

K_2CO_3. Normal Potassium Carbonate.—Called commercially pearl-ash, being obtained chiefly from wood-ashes. White, deliquescent, fusible, alkaline.

$KHCO_3$. Acid Potassum Carbonate or *Bicarbonate.*—Also called saleratus. Not so soluble as the normal salt, nearly neutral in reaction. Used as an antacid internally and in cooking.

KNO_3. Potassium Nitrate.—Also called nitre and saltpetre. This occurs in large natural deposits, formed by the decomposition of animal matter in the soil. This gives rise to nitric acid, which unites with the potassium already existing in the soil. This process is initiated and aided by man at present. A white permanent salt, neutral, quite soluble in water. Used to some extent in medicine and as an antiseptic, but chiefly in the manufacture of gun-powder. In the ordinary kind the reactions are thus:

$$3C+2KNO_3+S=3CO_2+K_2S+N_2.$$

In blasting-powder there is more C and CO is formed instead of CO_2. Late researches have shown that it is not near as simple as shown in the above equation. Many complex bodies are formed. One cubic inch of gun-powder makes about 280 cubic inches of gas, which is under a pressure of about 40,000 lbs. to the square inch, owing to the temperature.

$KClO_3$. Potassium Chlorate.—Easily parts with its O and is used in the mannfacture of it. Not combustible in itself, but when mixed with any combustible substance is explosive. Used in medicine to some extent, and largely on the tips of parlor matches to furnish the O necessary for combustion.

Baking-powders.—Used instead of yeast in the making of bread. Many are composed of sodium bicarbonate and KHC

H_4O_6, potassium bitartrate or cream of tartar. This mixture when heated becomes changed into $H_2O+CO_2+KNaC_4H_4O_6$ potassium sodium tartrate or Rochelle salt. The carbon dioxide inflates the bread. Alum is also used in baking-powders, but is considered by many to be injurious to health.

SODIUM—Na.

Properties.—Resemble those of K. Does not undergo spontaneous combustion unless the water is heated or the metal is prevented from moving. Burns with a yellow flame. Its spectrum consists of several bright lines in the yellow.

Occurrence.—Never native, but in its compounds universally distributed. Occurs in all rocks, waters, air, plants and animals. It is the most abundant metal known which forms so many soluble compounds. Sea-weeds prefer it to K, but the reverse is the case with land-plants. Its chief source is the sodium chloride found in sea-water and in brines.

Preparation.—Made in the same way as K, but no explosive compound is formed.

Uses.—The metal itself is chiefly used to make Al and it is the most expensive ingredient in the process. Its compounds have many uses.

COMPOUNDS.

Na Cl, Sodium Chloride.—Common salt. Sometimes occurs solid as rock-salt. Found in large quantities in the sea-water and in brines from which it is extracted by evaporation and crystallization. Quite soluble in water and about as soluble in cold as in hot water. Not deliquescent ordinarily but it is often contaminated with magnesium and calcium chlorides which are deliquescent. Is an antiseptic and on account of this used in preserving food, especially meat. Used in the manufacture of hard soaps.

Na Br and *Na I*—Resemble in their properties, preparation and uses the corresponding potassium compounds. Sodium iodide is deliquescent.

Na_2O and Na_2O_2.—Of no practical importance.

$Na\ OH$, *Sodium Hydroxide* or *Soda.*—Very similar in its properties and preparation to potassa but is less powerful. With fats it forms hard soaps.

$Na\ NO_3$, *Sodium Nitrate.*—Commonly called Chili saltpetre, because it occurs in large beds in Chili and Peru; due possibly to the decomposition of the excreta of birds. Deliquescent and hence cannot be used in gun-powder. Used very largely as a manure and in the manufacture of nitric and sulphuric acids.

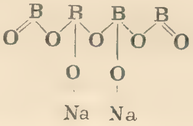
$Na_2\ CO_3$, *Normal Sodium Carbonate.*—Also called sal-soda or washing soda. Resembles in its properties potassium carbonate, but is efflorescent. It is more extensively used, especially in the manufacture of soaps and of glass. The term, soda, is often applied to this or to the following salt:

$NaHCO_3$, *Acid Sodium Carbonate* or *Bi-carbonate*, also called cooking-soda.

Na_2SO_4, *Sodium Sulphate.*—Found native in many mineral springs. When combined with 10 Aq., it is called Glauber's salt. Is used in medicine as a purgative.

$Na_2S_2O_3$, *Sodium Thiosulphate.*—Commonly called hyposulphite of soda. This is largely used in photography. It dissolves out the silver salts which have not been acted upon by the light. In that way it fixes the negative.

$Na_2B_4O_7$, *Sodium Biborate* or *Borax.*—The proper name for this is disodic pentametatetraborate. Efflorescent and not very soluble. Used in medicine and largely in blow-pipe experiments. Its grapic formula is



LITHIUM—LI.

Properties.—Resemble those of Na and K, but are weaker. Its spectrum shows one bright line in the red and a paler line in the yellow. Is extensively distributed but always in very minute quantities. Never native.

Compounds.—Of but little importance. They were formerly used internally for dissolving renal calculi. It was thought they would form the freely soluble lithium urate with uric acid, but this does not occur.

CÆSIUM—CS.

AND

RUBIDIUM—RB.

These are two rare metals, belonging to this group. They occur only in traces and were discovered by spectrum analysis. Of no importance.

AMMONIUM.

This a monad compound radical, having the composition $(NH_4)^i$. In all its chemical properties it resembles potassium very closely and for convenience is described with the alkaline metals.

Properties.—It has probably never been isolated. It has been supposed to form an amalgam with Hg but this is very doubtful.

COMPOUNDS.

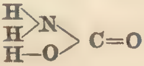
NH_4OH, Ammonium Hydrate.—This is probably formed when ammonia is dissolved in water, which at ordinary temperatures will take up about 700 times its volume of ammonia. The solution is called officinally *Aqua Ammoniae* and commonly ammonia. It resembles in its properties potassa but will not saponify fats. Is not as powerful a caustic.

NH_4Cl, Ammonium Chloride.—Commonly called sal ammoniac. Obtained from the ammoniacal liquor of the gas-works by adding hydrochloric acid, crystallizing and purifying. Volatile and not decomposed by sublimation, freely soluble. Used considerably in medicine.

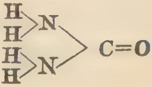
$(NH_4)_2$ CO_3, Ammonium Carbonate.—A white unstable salt. When exposed to the air gives off ammonia, NH_3, and becomes changed into the bicarbonate.

NH_4HCO_3, *Ammonium Bi-carbonate.*—A white, fairly stable salt, soluble. The officinal *Ammonii Carbonas* is a mixture of the bi-carbonate and carbamate of ammonium and its chemical formula is $NH_4HCO_3 . NH_4NH_2CO_2$. The common name is sal volatile. When dissolved in water the carbamate becomes changed into carbonate; when exposed to the air it becomes bi-carbonate.

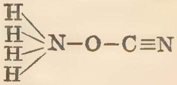
NH_2OHCO, Carbamic Acid.—This is carbonic acid in which the monad radical, NH_2, amidogen, has replaced one hydroxyl. Its graphic formula is



If another hydroxyl is replaced by amidogen it forms *$(NH_2)_2$ CO, Carbamide* or Urea, thus:



This is isomeric with *Ammonium Cyanate* which readily decomposes into urea. Its graphic formula is



METALS OF THE ALKALINE EARTHS.

These are Ba, Sr and Ca. They are all dyads, of a light yellow color, a little heavier than water. They decompose water, forming strong basic oxides, caustic, which in combination with water form feebly soluble hydroxides. Their carbonates are almost insoluble in water and are not alkaline. Each forms but one chloride.

BARIUM—BA.

Occurrence.—Never native. Fairly abundant, occurring as the sulphate, heavy-spar, and the carbonate.

COMPOUNDS.

BaO, Barium Monoxide or *Baryta.*—This when combined with water forms the hydrate, $Ba(OH)_2$, which is sparingly soluble in water. Baryta-water is used considerably instead of lime-water as a test for carbon dioxide, with which it forms an insoluble barium carbonate, $BaCO_3$.

BaO_2, Barium Dioxide.—This used considerably for preparing hydrogen peroxide; thus,

$$BaO_2+H_2SO_4=BaSO_4+H_2O_2.$$

$BaCl_2$, Barium Chloride.—A white, soluble salt, used considerably as a test for sulphuric acid and soluble sulphates, with which it forms the very insoluble barium sulphate.

All soluble salts of Ba are poisonous. The chemical antidote is any soluble sulphate, such as Epsom salt, Glauber's salt, etc.

STRONTIUM—Sr.

A rather rare metal, never native, occurring as the carbonate and sulphate. Not of much importance, the only practical use of its salts being in the formation of "Red Fire."

CALCIUM—Ca.

Occurrence.—The second most abundant metal in nature. Never native. The most important forms in which it is found are:

(1)—Calcium silicate. Wollastonite.
(2)—Calcium carbonate. Iceland spar, lime-stone, chalk, coral, marble, etc. All the carbonate is of animal origin, usually due to the skeletons and shells of minute animalcules.
(3)—Calcium sulphate + 2Aq. Gypsum, alabaster, selenite.
(4)—Calcium chloride. Found in many mineral waters.
(5)—Calcium fluoride. Fluorspar.
(6)—Calcium phosphate with the chloride and fluoride. Apatite.
(7)—In animals and plants as the phosphate and carbonate in combination with organic matter.

The metal itself is of little use.

COMPOUNDS.

CaO, Calcium Oxide or *Lime.*—White, infusible, escharotic. Prepared by heating calcium carbonate, thus

$$CaCO_3 + \text{heat} = CaO + CO_2.$$

When mixed with water it takes up one molecule with the development of considerable heat. This forms calcium hydrate, $Ca(OH)_2$, or slaked lime. Slaked lime is alkaline, slightly soluble in water, more so in cold than hot. One pint of water at the ordinary temperature dissolves about 11 grains. Lime-water is used considerably in medicine and as a test for carbon dioxide.

Mortar is a mixture of slaked lime with water and coarse, clean, sharp sand. It hardens, owing to the absorption of carbon dioxide from the atmosphere, thus

$$Ca(OH)_2+CO_2=CaCO_3+H_2O.$$

The sand also gradually combines with the slaked lime to form a silicate.

Hydraulic cements consist usually of clay, quick-lime and iron oxides, very carefully burnt. When this mixture is wet with water, a crystalline hydrated silicate of Al, Fe and Ca is formed. This is insoluble in water and sets under it.

$CaSO_4$, Calcium Sulphate.—This occurs native, combined with 2Aq, and then is called gypsum. When heated this gives off the 2Aq and can be powdered, forming plaster of Paris. When mixed with water, this again becomes crystalline from taking up water and sets. It is slightly soluble in water.

$CaCO_3$, Calcium Carbonate.—Very extensively distributed in nature. Almost insoluble in water, but with carbon dioxide forms a bicarbonate, $CaH_2(CO_3)_2$, which is quite soluble. The solution is neutral and can be decomposed simply by boiling.

Calcium Phosphates.—Very important. Three in number:

(1)—$Ca_3(PO_4)_2$, *tricalcic orthophosphate*, also called bone phosphate. This is the chief inorganic constituent of bone. Insoluble in water and hence worthless for manure.

(2)—$Ca_2H_2(PO_4)_2$ or $CaHPO_4$, *dicalcic orthophosphate*, also called reverted phosphate, insoluble in pure water.

(3)—$CaH_4(PO_4)_2$, *monocalcic orthophosphate*, also called soluble phosphate, superphosphate and acid phosphate. This is soluble in water and is used very extensively as a manure. It is prepared from (1) by means of sulphuric acid.

Chloride of Lime.—See page 15.

MAGNESIUM—Mg.

Occurrence.—Never native but very abundant. Usually associated with Ca. Occurs in the following forms:

(1)—Magnesium carbonate. Magnesite.
(2)— " and calcium carbonates. Dolomite.
(3)— " silicate. Talc, steatite, meerscham.
(4)— " and calcium silicates. Asbestos.
(5)— " sulphate. Epsom salt.
(6)— " chloride.—In sea-water and many mineral springs.
(7)—Ammonio—magnesian phosphate. In guano and decomposing urine.
(8)—In all plants and animals in association with Ca and similarly combined.

Preparation.—By heating the chloride with metallic Na; thus,

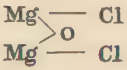
$$MgCl_2+2Na=2NaCl+Mg,$$

or by decomposing the fused chloride by electricity.

Properties.—A brilliant white metal, a little heavier than water, fusible and volatile at a bright red-heat. Permanent in dry air but oxidized in moist air. Burns with a brilliant light, so rich in actinic rays that it is used for photographing. It produces much smoke.

COMPOUNDS.

$MgCl_2$, Magnesium Chloride.—A white, very deliquescent salt, found in sea-water and many mineral springs. Forms with magnesia an oxychloride Mg_2OCl_2, the graphic formula of which is



This is very hard and is used for making statues and artificial stone.

MgO, Magnesium Oxide or *Magnesia.*—A white almost infusible powder. When moistened with water it shows an alkaline reaction and combines with it very slightly to form a hydrate, $Mg(OH)_2$. This is almost insoluble in water and the solution is not alkaline. When kept in suspension in water, it constitutes "milk of magnesia." Although very faintly alkaline, it will neutralize acids well and is used for that purpose.

$MgSO_4$, Magnesium Sulphate.—A white, soluble salt, found in many waters combined with 7 Aq. Commonly called Epsom salt. Used as a purgative.

$MgCO_3$, Magnesium Carbonate.—Insoluble in pure water but soluble in water containing carbon dioxide, with which it forms a bi-carbonate, $MgH_2(CO_3)_2$. The officinal *Magnesii Carbonas,* formerly called magnesia alba, is a mixture of magnesium carbonate and hydrate in varying proportions. It is prepared by mixing hot solutions of magnesium sulphate and potassum carbonate and boiling: thus,

$$2K_2CO_3+2MgSO_4+H_2O=2K_2SO_4+MgCO_3+Mg(OH)_2+CO_2.$$

If the solutions are concentrated, the precipitate is dense; if dilute, it is light and bulky.

ZINC—Zn.

Occurrence.—Never native. Fairly abundant, occurring chiefly as

(1)—Zinc sulphide. Zinc-blende.
(2)—Zinc carbonate. Calamine.

These ores are usually associated with Pb.

Preparation.—The ores are roasted, then mixed with powdered coal and heated. At a red-heat, the Zn distils over and is collected, carbon monoxide being separated.

Properties.—Bluish-white, more volatile than most metals, brittle at ordinary temperatures. If heated to 120° C., it becomes malleable; if it is rolled or hammered while at that temperature, it retains its malleability on cooling. It tarnishes a little in air, forming the oxide. Next to Fe, it is one of the cheapest metals. Of high electropositive value.

Uses.—Rolled out in sheets, it is used very largely as a protective. Also used considerably as the positive element in galvanic batteries. Galvanized iron consists of sheet-iron covered with Zn. Zn enters into many alloys, forming with Cu, brass and with Ni and Cu, German silver.

COMPOUNDS.

$ZnCl_2$, Zinc Chloride.—Very deliquescent, fusible and caustic. Very poisonous. The antidotes are the alkalies or their carbonates. Used in soldering copper surfaces, in preserving timber, in embalming bodies and as an escharotic. It forms an oxychloride similar to that of Mg and used for making artificial teeth.

ZnO, Zinc Oxide, also called zincite or zinc-white. A white, insoluble powder ; prepared by heating the carbonate : thus,

$$ZnCO_3 + \text{heat} = ZnO + CO_2.$$

Used in medicine externally, and as a pigment. Its advantages over white lead are that it does not blacken on exposure ot sulphur-fumes, because it forms a white sulphide, and it is not poisonous.

$ZnSO_4$, Zinc Sulphate.—With 7 Aq, this forms white vitriol. A white, permanent salt, a good antiseptic and disinfectant. Used in medicine as an emetic, as a counter-irritant and caustic.

CADMIUM—Cd.

Sources, etc.—Most zinc-ores, especially the blende. It is more volatile than Zn and is carried over in the first part of the distillate, from which it is afterwards purified. The only use of the metal is to form part of alloys and in that way lower their melting-point.

COMPOUNDS.

CdS, *Cadmium Sulphide.*—A yellow salt, used as a pigment. Better than chrome yellow, (lead chromate), for it does not blacken on exposure to sulphur-fumes, being already saturated with S.

CdI_2, *Cadmium Iodide*	Much used in photography.
$CdBr_2$, *Cadmium Bromide*	

LEAD—Pb.

Sources.—Never native. Occurs chiefly in the form of
(1)—Lead sulphide. Galena.
(2)—Lead carbonate. Cerusite.

Nearly all lead ores contain a certain proportion of Ag.

Preparation.—By continued roasting, the S or the CO_3 is completely driven off.

Properties.—A soft, bluish-white metal, with very little tenacity. Melts at 315° C. In moist air slowly tarnishes with the formation of a suboxide. For the action of water on Pb, see page 33.

Uses.—Very extensively in the form of water-pipes, roofing, tanks, etc.

COMPOUNDS.

PbO, *Plumbic Monoxide.*	Litharge.	Not of much importance.
PbO_2, *Plumbic Dioxide.*	Found in storage batteries.	
Pb_3O_4, *Triplumbic Tetroxide.*	Red lead.	
Pb_2O, *Plumbic Suboxide.*		

$PbCrO_4$, *Lead Chromate.*—Chrome yellow. Used considerably as a pigment.

$Pb(C_2H_3O_2)_2$, *Lead Acetate*, also called sugar of lead. A white, soluble, efflorescent salt; has a faint odor of vinegar and a sweetish taste, becoming astringent. Used with alum in dye-printing to act as a mordant. Used considerably in medicine.

PbS, Lead Sulphide.—A black, crystalline, insoluble salt, occurring native. Formed whenever sulphuretted hydrogen comes in contact with a lead-salt. It is this which makes the lead pigments so objectionable in places where there is liable to be decomposing animal matter. The only advantage is that it may show that the air is contaminated with decomposing organic matter in places where that ought not to obtain access.

White Lead.—This is the common name for the officinal *Plumbi Carbonas.* It is really a mixture of lead carbonate, $PbCO_3$, and lead hydrate, $Pb(OH)_2$. It is used very extensively as a pigment, In medicine, used to some extent externally.

Lead-plaster. This is really lead oleate. It is formed by heating litharge and water with olive oil, which consists chiefly of olein, glycerine oleate; thus,

$$2C_3H_5(C_{18}H_{33}O_2)_3+3PbO+3H_2O=2C_3H_5(OH)_3+3Pb(C_{18}H_{33}O_2)_2.$$

All soluble salts of Pb are acute irritant poisons. The chemical antidote is any soluble sulphate, which forms an insoluble lead sulphate.

Chronic Plumbism.—The sources for the lead in this disease are almost innumerable; lead-pipes, lead-tanks, face-washes. hair-dyes, paints, all manufactures connected with lead, and many alloys.

COPPER—Cu.

Sources.—(1)—Native, especially in the Michigan mines.
(2)—Cupric sulphide. Copper glance.
(3)—Copper and iron sulphide. Copper pyrites.
(4)--Cupric carbonate. Malachite.
(5)—Cuprous oxide. Cuprite or Red oxide.

It occurs in a few other conditions, but these are the chief ones.

Properties.—A reddish metal, about nine times as heavy as water, very tenacious, ductile and malleable. Fusible and slightly volatile. Permanent in dry air, but in moist becomes covered with a green crust of the carbonate.

Uses.—Chiefly in alloys, although to some extent pure. With Zn it forms brass and muntz-metal. With Sn it forms bronze, gun-metal, speculum-metal, etc. Many of these alloys contain small quantities of Pb. With P it forms phosphor-bronze and with Al, aluminium-bronze. It enters into the alloys of gold and silver coins.

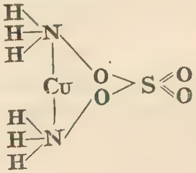
COMPOUNDS.

Cu forms two sets of compounds, the cuprous and the cupric. The former are few and unimportant, excepting the oxide. For the construction of the two sets see under "Graphic Formulæ," page 56.

$Cu(C_2H_3O_2)$, Cupric Acetate.—This is a salt used in medicine, called officinally *Cupri Acetas.* Quite soluble.

$CuSO_4$, Cupric Sulphate.—When combined with 5Aq, called blue vitriol. Quite soluble. Used considerably in medicine as a mild escharotic and emetic. Is an essential ingredient of Daniell's galvanic battery.

This forms with a solution of ammonia a double salt, Cupro-diammonium Sulphate, $(NH_3)_2\ Cu\ SO_4$. It is used as a test for As. Its graphic formula is



All soluble copper salts are poisonous. The antidotes are potassium ferrocyanide, the alkalies and their carbonates, and the albumens, such as milk, white of eggs, etc.

MERCURY—Hg.

Sources.—Almost entirely as mercuric sulphide, cinnabar, in which a little metallic Hg is found.

Preparation.—By roasting the sulphide, the S is oxidized to SO_2 and escapes while the Hg distills over.

Properties.—A silver-white, lustrous metal, liquid at ordinary temperatures, volatile at all temperatures above −13° C. Solid at −38.8° C. and boils at 350° C. Its specific gravity is 13.59. Unaltered in the air at ordinary temperatures, but above 300° C. it forms mercuric oxide. Like Cd, its molecule in the state of vapor consists of but one atom. It is sometimes adulterated with Pb or Sn, and if so, drops of the metal when rolled become tailed instead of remaining spherical.

Uses.—To make amalgams; in thermometers, barometers, etc. Its salts are much used in medicine. The fulminate is used in percussion-caps.

COMPOUNDS.

Like Cu, it forms two sets of compounds, mercurous and mercuric, both very important. For their construction see "Graphic Formulæ," page 56.

Hg_2Cl_2, Mercurous Chloride.—Commonly called calomel. The officinal name is *Hydrargyri Chloridum Mite.* It is a heavy, white, insoluble powder, volatile. May be prepared in several different ways:

(1)—By heating Hg with mercuric chloride:

$$Hg + HgCl_2 = Hg_2Cl_2.$$

(2)—By adding Hg and sodium chloride to mercuric sulphate and heating:

$$Hg + 2NaCl + HgSO_4 = Hg_2Cl_2 + Na_2SO_4.$$

(3)—By mixing a solution of mercurous nitrate with one of sodium chloride:

$$Hg_2(NO_3)_2+2NaCl=2NaNO_3+Hg_2Cl_2.$$

(4)—By mixing a solution of mercurous nitrate with one of mercuric chloride:

$$Hg_2(NO_3)_2+HgCl_2=Hg_2Cl_2+Hg(NO_3)_2.$$

$HgCl_2$, Mercuric Chloride.—Also called corrosive sublimate and bichloride of mercury. The officinal name is *Hydrargyri Chloridum Corrosivum.* A white, volatile salt, soluble in 16 parts of cold water and freely in alcohol and ether. Is strongly antiseptic. Very poisonous, the antidote being albumen. Is prepared by subliming mercuric sulphate with sodium chloride: thus,

$$HgSO_4+2NaCl=Na_2SO_4+HgCl_2.$$

May be made by heating Hg in Cl.

Hg_2I_2, Mercurous Iodide.—Also called protiodide. The officinal name is *Hydrargyri Iodidum Viride.* A yellowish-green, insoluble salt, prepared by mixing solutions of potassium iodide and mercurous nitrate: thus,

$$Hg_2(NO_3)_2+2KI=Hg_2I_2+2KNO_3.$$

HgI_2, Mercuric Iodide.—Also called biniodide. The officinal name is *Hydrargyri Iodidum Rubrum.* A bright-red, tasteless, odorless powder, almost insoluble in water, sparingly soluble in alcohol, freely soluble in solution of potassium iodide or mercuric chloride. Prepared by mixing solutions of mercuric chloride and potassium iodide together: thus,

$$HgCl_2+2KI=HgI_2+2KCl.$$

If the potassium iodide is in excess, it forms with the mercuric iodide a definite compound, $HgI_2.2KI$, which in a solution of potassa constitutes the Nessler re-agent.

Hg_2O, Mercurous Oxide.—An almost black, heavy, insoluble powder. It is the essential ingredient of "black wash," which is made by mixing mercurous chloride with lime-water : thus,

$$Hg_2Cl_2+Ca(OH)_2=Hg_2O+CaCl_2+H_2O.$$

HgO, Mercuric Oxide.—This exists in two forms, both insoluble :

(1)—A yellow, amorphous powder, called officinally *Hydrargyri Oxidum Flavum ;* prepared by mixing a solution of mercuric chloride with liquor potassæ : thus,

$$HgCl_2+2KOH=HgO+2KCl+H_2O.$$

(2)—A red crystalline powder, called officinally *Hydrargyri Oxidum Rubrum.* Prepared by heating mercuric nitrate ; thus,

$$Hg(NO_3)_2+\text{heat}=HgO+N_2O_5,$$

the nitrogen pentoxide going off as vapor.

$Hg_2(NO_3)_2$, Mercurous Nitrate.—A white, soluble salt, prepared by acting with dilute nitric acid on Hg : thus,

$$6Hg+8HNO_3=3Hg_2(NO_3)_2+N_2O_2+4H_2O.$$

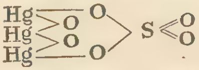
$Hg(NO_3)_2$, Mercuric Nitrate.—A white, deliquescent salt, prepared by acting with concentrated nitric acid on Hg : thus,

$$3Hg+8HNO_3=3Hg(NO_3)_2+N_2O_2+4H_2O.$$

A solution of this in dilute nitric acid constitutes the officinal *Liquor Hydrargyri Nitratis.*

$HgSO_4$, Mercuric Sulphate.—A white crystalline salt, decomposed by water with the formation of a basic salt, $Hg\,SO_4$.

2HgO. This is the officinal *Hydrargyri Subsulphas Flavus*, commonly called turpeth mineral. Its graphic formula may be expressed thus :



If the washing is long continued, all the sulphuric oxide will be washed away, leaving only the mercuric oxide.

NH_2HgCl, Mercurammonium Chloride.—A white, volatile precipitate, infusible because it volatilizes before melting, called officinally *Hydrargyrum Ammoniatum.* It is prepared by mixing a solution of mercuric chloride with aqua ammoniæ : thus,

$$HgCl_2+2NH_4OH=NH_2HgCl+NH_4Cl+2H_2O.$$

$(NH_3)_2HgCl_2$, Mercuro-diammonium Chloride.--Fusible white precipitate.

NHg_2I, Dimercurammonium Iodide.—This is the salt formed by the Nessler re-agent with ammonia : thus,

$$2(HgI_2.\ 2KI)+NH_3+3KOH=NHg_2I+7KI+3H_2O.$$

It constitutes the most delicate reaction known for ammonia.

SILVER—Ag.

Sources.—Occurs native to some extent, but its principal ores are the sulphide, carbonate, bromide and chloride. It is always associated with other metals, especially Pb and Au.

Preparation.—The ore is roasted with sodium chloride, which forms silver chloride. It is then agitated with iron scraps and the metal is precipitated : thus,

$$6AgCl+2Fe=Fe_2Cl_6+6Ag.$$

Hg is now added, forming an amalgam with Ag, which is separated by washing. The amalgam is then heated, Hg is distilled off and metallic Ag left behind.

Properties.—A white, lustrous metal, very malleable and ductile: probably the best conductor of heat and electricity known. Fusible but does not oxidize at any temperature and is unaffected by water. It is but feebly attacked by hydrochloric acid, rather more by sulphuric, and is easily dissolved by nitric acid, forming silver nitrate.

Uses.—The pure metal is but little used, on account of its softness, but alloyed with Cu, it is used very extensively for ornaments, coins, etc. The silver coins of the United States contain 90 per cent. of Ag and 10 per cent. Cu. Those of Great Britain contain 92.5 per cent. of Ag and 7.5 per cent. of Cu. It is also added to Au to increase its hardness.

COMPOUNDS.

AgCl, Argentic Chloride.—A heavy white precipitate, insoluble in water or nitric acid; soluble in ammonia but reprecipitated from that on the addition of nitric acid. It blackens on exposure to light, even if pure but much more rapidly if organic matter is present, forming a subchloride, Ag_4Cl_2, and liberating Cl. On this account it is much used in photography. It is easily dissolved by sodium thiosulphate.

AgBr, Argentic Bromide.—Resembles very closely the preceding. Much used in photography.

AgI, Argentic Iodide.—Resembles the chloride but is more stable; does not blacken unless there is some substance present capable of taking up the liberated I. Is not soluble in ammonia. Used extensively in photography.

$AgNO_3$, Argentic Nitric.—A white, fusible, soluble salt, prepared by acting on Ag with nitric acid. When melted and cast into sticks it is called officinally *Argenti Nitras Fusus*, commonly lunar caustic. It is a superficial caustic, forming an albuminate of Ag which darkens on exposure to the light from its reduction to silver oxide, Ag_2O, and metallic Ag. Besides its use in medicine, silver nitrate enters into the composition of indelible inks and is much used in photography. It

is poisonous, the antidote being any soluble chloride, such as common salt, which forms the insoluble silver chloride.

ALUMINIUM—Al.

Occurrence.—The most abundant metal known. Never native. Occurs as a silicate in felspar and clay, in corundum and its varieties, emery, ruby and sapphire, in the emerald.

Properties.—A white metal, very tenacious, malleable and ductile. Very light, its specific gravity being only 2.6. It can be made very rigid. As a conductor of heat and electricity, it is inferior only to Ag, if at all. It is not affected by the air or moisture or sulphuretted hydrogen. It is not attacked by ordinary acids except hydrochloric but is readily dissolved by caustic potash and soda.

Preparation.—By heating the fused chloride with metallic Na; thus, $Al_2Cl_6+6Na=6NaCl+2Al$.

Uses.—It is not much used at present, owing to its high price. It has some uses in astronomical instruments and jewelry. On account of its abundance and the important qualities it possesses, it will be extensively used as soon as a cheap way of preparing it can be found. As this age is known as the Iron Age and the preceding one the Bronze Age, so the succeeding one will be called the Aluminium Age.

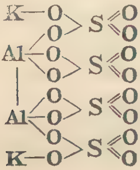
COMPOUNDS.

Al is a tetrad but it is always doubled in the molcule and thus two of the bonds are lost, making the double atom sexvalent. See under "Graphic Formulæ," page 56.

Al_2O_3, Aluminium Oxide or *Alumina.*—A heavy, white substance, forming with water $Al_2(OH)_6$, aluminium hydrate. This latter is used in dyeing as a mordant, since it makes insoluble compounds called lakes, with the vegetable colors.

$Al_2(SO_4)_3$, Aluminium Sulphate.—A white, crystalline powder, freely soluble. Used as a styptic and antiseptic.

$Al_2K_2(SO_4)_4$—*Potassio-Aluminium Sulphate* or *Alum.*—A colorless, crystalline salt, containing 24Aq., with a sweetish astringent taste, quite soluble. It is used considerably in medicine, in baking-powders, in dyeing, etc. Its graphic formula is :



The salt described above is the officinal *Alumen* but there are many other alums, all isomorphous with potash-alum. Thus K in the above compound can be replaced by Na, Li, Cs, Rb, ammonium, Ag or Tl. The Al can be replaced by Fe, Cr, and Mn. In the latter case it seems hardly correct to call it an alum, but the terms, chrome-alum, iron-alum, etc., are very commonly used.

PORCELAIN.—Is compact and translucent. Made from the following materials :

(1)—Kaolin, a very pure clay (aluminium silicate).

(2)—Pulverized quartz (silica), which prevents shrinking during baking.

3)—Felspar (aluminium and potassium silicate), which acts as a flux.

The glazing is made from the same materials but contains more felspar.

STONE-WARE.—Is compact but opaque. Made from clay containing ferric oxide and lime, on account of which it is partly fusible. The glazing is done by sodium chloride, which is decomposed and forms a sodium silicate.

EARTHENWARE.—Is porous. Made from clay containing a little felspar and silica, which render it partly fusible. The glazing consists largely of Pb and is dangerous from its liability to be attacked by acids.

GLASS.—Consists of the silicates of at least two bases with an excess of silica. There are several varieties, the more important being

(1)—Crown-glass, containing Na, Ca and Si.
(2)—Bohemian glass, containing K, Ca and Si.
(3)—Flint-glass, containing K, Pb and Si.

Green glass usually contains some Fe.

There is a group of five elements which have some properties in common. Their atomic weights are all between 52 and 59, many of their compounds are similiarly formed, they are often associated in ores. These metals are Mn, Cr, Co, Ni and Fe. Of these Mn, Cr and Fe form acids, Co, Ni andFe are magnetic. It has lately been stated that CO and Ni are simply compounds of one element, which it is claimed has been isolated. The group is usually called the Iron Group.

IRON—Fe.

Properties.—A soft, white, lustrous metal, the most magnetic and tenacious of all metals. Fuses with difficulty but can be welded. It is distinctly fibrous but becomes crystalline after being subjected to repeated jars and vibrations. This crystalline form, which is probably cubical, is much less tenacious than the fibrous. It is only oxidized in dry air at a red-heat and not at all in pure water. If any O or carbon dioxide is present in the water, it speedily forms rust. Commercially it exists in three forms :

(1)—Wrought-iron. This is nearly pure iron and has the characters of that.

(2)—Cast-iron. This always contains 2-6 per cent. of C and some Si, usually a little P and occasionally Mn. It is readily fusible and easily cast but will not weld. It expands slightly on solidification. Cannot be tempered. Is more brittle and less tenacious.

(3)—Steel. Contains .5—2. per cent. of C and in Bessemer steel, .5—2. per cent. of Mn. Less fusible than cast-iron but more than wrought-iron. Can be tempered and will bear a cutting edge. When of good quality, it is more tenacious and elastic than wrought-iron.

Preparation.—Cast-iron is usually first made directly from the ores and then from it the wrought-iron and steel. In the manufacture of cast-iron, the ore, if not already an oxide, is roasted to convert it into ferric oxide. This is then put into a blast-furnace with coal and lime-stone. The lime unites with the Si present in the ore and forms a fusible slag, which floats on top. The coal takes up the O, forming CO_2, and some of the coal unites with the iron, rendering that fusible. The slag is drawn off from the side and at intervals the bottom is tapped and the raw metal allowed to run out into moulds.

Wrought-iron is obtained by heating the cast-iron in a reverberatory furnace. In this a certain amount of ferric oxide is formed which oxidizes the C and Si present, forming carbonic dioxide and a fusible silicate of the oxide. As these changes go on, the iron becomes less fusible and is finally collected into large balls, which are put under heavy hammers. By these the silicate is squeezed out and the iron left comparatively pure.

Steel is made in some cases directly from the ores or cast-iron by processes too intricate to be described here. It can be made from wrought-iron by placing bars of that in a crucible filled with C. This is then exposed for several hours to a red heat. The iron takes up the C and becomes steel.

Sources.—A very little is found native, almost entirely in the form of meteorites. Its chief ores are :

(1)—Iron bisulphide. Iron pyrites.
(2)—Ferroso-ferric oxide. Magnetic iron-ore or load-stone.
(3)—Ferric oxide. Red hæmatite.
(4)—Ferrous carbonate. Clay iron-stone.

COMPOUNDS.

There are two sets of compounds, the ous- and the ic-salts. In the former it is supposed to be bivalent. In the latter it is quadrivalent, but, like Al, it is arranged in a double molecule, which is but sexvalent. See page 57.

$FeCl_2$, Ferrous Chloride.—This is prepared by acting on Fe with hydrochloric acid; thus,

$$2HCl+Fe=FeCl_2+H_2.$$

Fe_2Cl_6, Ferric Chloride.—A crystalline, red, deliquescent salt, with a very strong astringent taste. Made by acting on the ferrous chloride with hydrochloric and nitric acids; thus,

$$6FeCl_2+2HNO_3+6HCl=3Fe_2Cl_6+N_2O_2+4H_2O.$$

It is the officinal *Ferri Chloridum.*

FeI_2, Ferrous Iodide.—A greenish, unstable, deliquescent salt. It is the officinal *Ferri Iodidum.*

FeO, Ferrous Oxide.—A dark-gray, insoluble powder, very unstable and rapidly oxidizing to ferric oxide.

Fe_2O_3, Ferric Oxide.—A crystalline, red, insoluble powder, not acted on by the magnet. Ochre consists of clay colored with this.

Fe_3O_4, Ferroso-Ferric Oxide.—This occurs native as the magnetic iron-ore or load-stone. It does not form any salts.

$Fe_2(OH)_6$, Ferric Hydrate.—This in combination with a little ferric chloride constitutes *Ferrum Dialysatum.* It is made by mixing ammonia with a solution of ferric chloride; thus,

$$6NH_4OH+Fe_2Cl_6=Fe_2(OH)_6+6NH_4Cl.$$

The latter is removed by dialysis, leaving the colloid hydrate behind. The solution is of a reddish-brown color, free from astringency. Its medicinal use is of doubtful value. Ferric hydrate when freshly prepared is an antidote to As. (See Arsenic, page 94.) Rust usually consists of this hydrate more or less dehydrated, thus: $Fe_2O(OH)_4$ or $FeO_2(OH)_2$.

$FeSO_4$, Ferrous Sulphate.—When combined with 7Aq, it is commonly called green vitriol or copperas. A green, efflorescent salt, freely soluble; found native in some mineral waters. It is the officinal *Ferri Sulphas.* It is a mild astringent and disinfectant. It is much used internally, especially in the form of Blaud's pills. These contain equal parts of the sulphate and potassium carbonate. As a result of the double decomposition, ferrous carbonate and potassium sulphate are formed. Ferrous sulphate is largely used in dyeing and with tannic acid and logwood to make inks.

$Fe_2(SO_4)_3$, Ferric Sulphate.—A reddish-brown, amorphous salt, soluble and when in solution astringent and somewhat irritating. It enters into the officinal *Liquor Ferri Tersulphatis.*

$FeCO_3$, Ferrous Carbonate.—Found native in clay iron-stone and in some mineral springs. Is somewhat soluble in water, especially when it contains free carbon dioxide. It enters into the officinal *Ferri Carbonas Saccharatus.*

Phosphates.—The ous-phosphates are formed similarly to those of Ca, (page 68). Ferric phosphate is $Fe_2(PO_4)_2$. Ferric pyrophosphate is $Fe_4(P_2O_7)_3$. All the phosphates are insoluble. The officinal *Ferri Pyrophosphas,* which is quite soluble, is really a sodio-ferric compound.

COBALT—Co.

Properties, etc.—A white, brittle, very tenacious metal, almost infusible; strongly magnetic. It is usually found associated with Ni.

COMPOUNDS.

Like Fe this forms two series of compounds, ous and ic. The latter are quite unstable.

CoO, *Cobaltous Oxide.*—This is largely used for staining glass blue.

$CoCl_2$, *Cobaltous Chloride.*—This in solution constitutes blue sympathetic ink. Characters written with it are invisible until heated, when it becomes anhydrous, blue and visible. On cooling it again absorbs water and becomes invisible.

NICKEL—Ni.

Properties, etc.—A white, malleable metal, almost infusible and less oxidizable than Fe. Very magnetic. It is usually associated with Co, its chief ore being an arsenide, called kupfernickel. It is used somewhat in alloys and largely to form a non-oxidizable covering to other metals.

MANGANESE—Mn.

Properties, etc.—A reddish, hard, brittle metal, decomposing water at all temperatures. It materially improves the quality of cast-iron and steel and is used considerably in their manufacture. It occurs in the form of manganic oxide, mangano-manganic oxide and manganese dioxide.

COMPOUNDS.

This forms two not very definite series of ous and ic compounds and several that belong to neither group.

MnO, *Manganous Oxide* }
Mn_2O_3, *Manganic Oxide* } These are both basic oxides. The latter occurs native as Braunite.

Mn_3O_4, *Mangano-manganic Oxide* MnO_2, *Manganese Dioxide*	These are both neutral. The former occurs as Pyrolusite or black oxide of Mn, the latter as Hausmannite.

MnO_3, *Manganese Trioxide.*—This is a hypothetical acid oxide, which forms with the alkalies, salts called manganates. Potassium manganate, K_2MnO_4, is a green crystalline salt, soluble in water and when in solution, known as Condy's Green Fluid. It is a disinfectant and deodorizer.

Mn_2O_7, *Manganese Heptoxide.*—This is an acid oxide, which forms with water permanganic acid, $H_2Mn_2O_8$. Potassium permanganate, $K_2Mn_2O_8$, is a crystalline, purple salt, soluble in water. It is very easily reduced by organic matter and is used as a test for it. It is a disinfectant and deodorizer. In solution in water it constitutes Condy's Red Fluid.

CHROMIUM—Cr.

Properties, etc.—A very hard, almost infusible metal, found in chrome iron-stone, which consists of a mixture of ferrous and chromic oxides.

COMPOUNDS.

It also forms two series of compounds, ous and ic, and several which belong to neither.

CrO, *Chromous Oxide* Cr_2O_3, *Chromic Oxide*	Both are basic. Owing to its great insolubility, the latter is used for printing greenbacks.

CrO_2, *Chromium Dioxide* Cr_3O_4, *Chromo-chromic Oxide*	Both neutral.

CrO_3, *Chromium Trioxide.*—A brilliant red compound, very deliquescent and easily reduced by organic matter. It is antiseptic. It is used considerably in medicine as an escharotic under the officinal name of *Acidum Chromicum*. With water it forms

H_2CrO_4, Chromic Acid.—This forms a series of salts, the chromates, of which potassium chromate, K_2CrO_4, is the best known and most used. This acid forms another acid, which bears the same relation to it that pyrosulphuric acid bears to sulphuric. It can be formulated thus:

$$2H_2CrO_4 - H_2O = H_2Cr_2O_7.$$

The natural name for this would be pyrochromic acid, but its salts are known as bichromates. The most important of these is potassium bichromate, $K_2Cr_2O_7$, which is used very extensively in the arts.

Many of the chromium compounds are used as pigments, owing to their brilliant colors.

GOLD—Au.

Properties.—A soft, yellow metal, more malleable than any other, fusible at a bright red heat. Not affected by air or water at any temperature, nor by ordinary acids. It is dissolved by a mixture of nitric and hydrochloric acids with the formation of auric chloride, $AuCl_3$. This mixture, which is called nitrohydrochloric acid, or *aqua regia*, gives rise to nascent Cl when freshly prepared; thus,

$$6HCl + 2HNO_3 = 4H_2O + N_2O_2 + 6Cl.$$

Sources.—Very widely distributed, though rarely in paying quantities. Always native and nearly always associated with Ag and sometimes Pb.

Uses.—It is too soft to be used pure. It is always alloyed with some Ag and often Cu. The gold coins of the U. S. consist of Au 90 per cent. and Ag and Cu 10 per cent.; of Great Britain, of eleven-twelfths of Au.

COMPOUNDS.

It forms two sets of compounds, ous and ic. In the former it is univalent, in the latter trivalent. The former are quite unstable.

Au_2O_3, Auric Oxide.—A brown, insoluble powder, easily reduced by the light. It is an acid oxide and forms with the alkalies, salts called aurates, thus:

$$2KOH + Au_2O_3 = 2KAuO_2 + H_2O.$$

Au forms hardly any oxygen-salts, but does form chlorides and bromides.

TIN—Sn.

Properties.—A soft, white, malleable metal, fusible. Is not acted upon by air or water at ordinary temperature. Heated a little above its melting-point, it burns with the formation of stannic oxide. Block tin is pure tin in mass.

Sources.—It occurs almost entirely as stannic oxide, called tin-stone or cassiterite; rarely as the sulphide.

Preparation.—The ore is crushed and heated with coal. Carbon dioxide escapes and the metal is run into large blocks.

Uses.—Most tin-ware consists of sheet-iron covered with a layer of Sn to protect it from the oxidizing effects of the air. Sn enters into many alloys, such as pewter, gun-metal, bronze, etc. Its salts are largely used in dyeing and in calico-printing.

COMPOUNDS.

It forms two sets of compounds, ous and ic. In the former it is bivalent, in the latter tetravalent.

SnO, Stannous Oxide.—A dense, black powder forming with water stannous hydrate, $Sn(OH)_2$. This is a basic oxide and forms the stannous salts with acids.

SnO_2 Stannic Oxide.—A heavy, white, powder, not attacked by any acid. This is both a basic and an acid oxide. It forms with acids the stannic salts, while with water it forms two acids, stannic acid, H_2SnO_3, and metastannic acid, $H_{10}Sn_5O_{15}$. The former is the more important. Of its salts sodium stannate, Na_2SnO_3, is largely used in calico-printing as a mordant.

BISMUTH—Bi.

Properties.—A reddish-white, very brittle metal, fusible and volatile; but little affected by the air. It is the most diamagnetic of all substances.

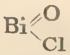
Sources.—The most important ore is the native metal, associated with cobalt, nickel and tin ores.

Uses.—The metal itself is but little used except in alloys, upon which it confers easy fusibility and the property of expanding on solidification. Its compounds are used considerably in medicine.

COMPOUNDS.

Bi forms two sets of compounds, ous and ic; in the former it is trivalent and in the latter quintivalent. The former are the more stable and the more numerous but they are readily decomposed by water with the formation of basic salts which are insoluble.

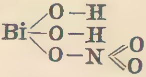
$BiCl_3$, Bismuth Trichloride or Bismuthous Chloride.—A white, fusible salt which when placed in water forms an insoluble oxychloride, Bi OCl. Its graphic formula is



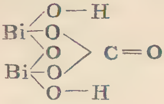
$Bi(NO_3)_3$, Bismuthous Nitrate.—When this is put into a large amount of water, it forms a basic nitrate, $BiNO_3(OH)_2$: thus.

$$Bi(NO_3)_3+2H_2O=BiNO_3(OH)_2+2HNO_3.$$

This is the officinal *Bismuthi Subnitras.* Its graphic formula is



$Bi_2OCO_3(OH)_2$—This is the officinal *Bismuthi Subcarbonas.* Its graphic formula is



$BiC_6H_5O_7$, *Bismuth Citrate.*—This is a salt, soluble in aqua ammoniae. With this it forms a permanent soluble compound called officinally *Bismuthi et Ammonii Citras.* As it is soluble, it is lacking in the virtues of the subnitrate and subcarbonate.

ANTIMONY—Sb.

Properties.—A bluish-white, very brittle metal, fusible and volatile. Not acted on by the air at ordinary temperatures.

Sources.—Almost entirely from the native antimonious sulphide, called stibnite.

Uses.—It enters into many alloys, such as type-metal, made of Pb and Sb; Britannia-metal, made of Sn and Sb, etc.

COMPOUNDS.

It forms two sets of compounds, ous and ic. In the former it is trivalent, in the latter quintivalent. Nearly all the antimony compounds are decomposed by water.

$SbCl_3$, *Antimonious Chloride.*—A white, deliquescent salt, formerly called butter of antimony. It is prepared by heating antimonious sulphide with hydrochloric acid; thus,

$$Sb_2S_3+6HCl=2SbCl_3+3H_2S.$$

$SbCl_5$, Antimonic Chloride.—A colorless, volatile liquid, quite unstable.

Sb_2S_3, Antimonious Sulphide.—A compound of a gray color when pure, but when combined with a little water, of an orange red color. It is formed whenever sulphuretted hydrogen acts on a soluble salt of Sb; thus,

$$2SbCl_3+3H_2S=Sb_2S_3+6HCl.$$

Sb_2S_5, Antimonic Sulphide—of little consequence.

$KSbOC_4H_4O_6$, Potassio-stibyl tartrate.—This is known officinally as *Antimonii et Potassii Tartras*, commonly as tartar-emetic. This is prepared by boiling antimonious oxide, Sb_2O_3, with potassium bitartrate, $KHC_4H_4O_6$;

$$Sb_2O_3+2KHC_4H_4O_6=2KSbOC_4H_4O_6+H_2O.$$

It is a white, crystalline salt, freely soluble in water. Its graphic formula will be given under tartaric acid.

The tests will for Sb will be given in Chapter X.

ARSENIC—As.

Properties.—A gray, brittle metal, slowly oxidizing in the air. It volatizes without fusion, and if O be present, forms arsenious oxide, which has a garlicky odor. In many of its chemical properties it resembles P, and is sometimes grouped with the non-metals.

Occurrence.—It is very widely distributed but usually only in small quantities. It is sometimes found native, but its chief ores are a sulphide of Fe and As, called mispickel, and arsenides of Co and Ni.

Preparation.—By heating the ore, the As sublimes in the form of arsenious oxide and is condensed and afterwards purified by resublimation with charcoal.

Uses.—It is used somewhat in alloys, being added to Pb in the manufacture of shot to make them round; also to Fe and Cu to enable them to take a more brilliant polish.

COMPOUNDS.

It forms two sets of compounds, ous and ic. In the former it is trivalent, and in the latter quintivalent.

As_2O_3, *Arsenious Oxide.*—This is commonly called white arsenic or simply arsenic. A white, crystalline compound, fusible and after fusion solidifying into a glassy mass, transparent at first but becoming opaque. Slightly soluble in water, forming with it arsenious acid, H_3AsO_3. This with some of the metals forms arsenites, most of which are unstable. At about 218° C, it is volatilized. It has a very slight taste, which can be easily disguised. It is known officinally as *Acidum Arseniosum.*

As_2O_5, *Arsenic Oxide.*—A strong acid oxide, forming with water arsenic acid, H_3AsO_4, which resembles in many chemical properties phosphoric acid. This forms with many metals stable salts called arseniates. This oxide is poisonous but less than the preceding.

Na_2HAsO_4—*Disodic Arseniate.*—A white, crystalline, soluble salt, known officinally as *Sodii Arsenias.*

K_3AsO_3, *Potassium Arsenite.*—This is probably the salt contained in the officinal *Liquor Potassii Arsenitis*, known commonly as Fowler's solution.

$Cu_3(AsO_3)_2$, *Cupric Arsenite.*—This is a brilliant, insoluble green salt, commonly called *Scheele's green. Paris* or *Schweinfurt green*, is a mixture of the acetate and arsenite of copper in varying proportions. Both are extensively used as pigments, especially for wall-paper. They are not volatile, but particles may be rubbed off and float in the air. This may happen to such an extent as to cause symptoms of chronic arsenical poisoning, especially if bed-rooms are covered with this kind of paper.

$Fe_3(AsO_4)_2$, *Ferrous Arseniate.*—It is a white amorphous powder, officinal in the British Pharmacopœia. The average dose contains so little iron that its chief value must be due to the As in it.

As_2S_2, *Arsenic Disulphide.*—It is an orange-red, fusible salt, occurring native as Realgar. It is used a little as a pigment.

As_2S_3, *Arsenious Sulphide.*—It is a yellow, fusible salt, occurring native as Orpiment. It is used as a pigment.

Both of these sulphides are said to be harmless when perfectly pure. If made artificially, they are very apt to contain some arsenious oxide and are then of course very poisonous.

Nearly all arsenical compounds are poisonous. The antidote in general is ferric hydrate, freshly prepared. This is made in two ways.

(1)—By mixing solutions of ferric sulphate and ammonia: thus,

$$Fe_2(SO_4)_3+6NH_4OH=Fe_2(OH)_6+3(NH_4)_2\ SO_4.$$

(2)—By mixing solutions of ferric sulphate and magnesium hydrate; thus,

$$Fe_2(SO_4)_3+3Mg(OH)_2=Fe_2(OH)_6+3MgSO_4.$$

The latter is the preferable way, for the magnesium sulphate is a purgative. The ferric hydrate acts by forming a basic arseniate which is insoluble and permanent: thus,

$$2Fe(OH)_6+As_2O_3=Fe_2(AsO_4)_2.\ Fe(OH)_2+5H_2O.$$

The tests for As will be given in Chapter X.

PLATINUM GROUP.

In this are included platinum, iridium, palladium, rhodium, ruthenium and osmium. These metals have some common chemical properties and are nearly always found associated in nature. The only one of sufficient importance to be described here is platinum.

PLATINUM—Pt.

Properties.—A white, very malleable and ductile metal. The heaviest substance known, its specific gravity being 21.5. Almost infusible. Not attacked by the air, water or ordinary acids; only by nitro-hydrochloric acid.

Occurrence.—Always native but not very abundant. Associated in its ores with the others of this group and often with Ag.

Uses.—It is used extensively in crucibles where infusibility is required and in laboratory-ware where marked chemical stability is needed.

COMPOUNDS.

Are of little consequence compared with the native metal. They are in two sets, ous and ic. In the former it is bivalent, in the latter quadrivalent.

$PtCl_4$, *Platinic Chloride.*—A reddish-brown, deliquescent salt, much used as a test-reagent for K. With the chloride of this it forms a yellow precipitate, soluble only in 60 parts of water and still less in dilute alcohol.

CHAPTER IX.

ORGANIC CHEMISTRY.

This is the Chemistry of the Carbon Compounds, which are produced in animals and plants, and their derivatives. These compounds are not necessarily due to animal or vegetable life, since many of them can be formed by synthesis. In fact the laboratory of to-day almost surpasses nature in the formation of these compounds. These compounds always contain C, usually H, often O and N, and any element may be represented. Their general characteristics are:

(1)—They usually contain many atoms, but few elements.

(2)—They often exhibit great complexity of structure.

(3)—They are often unstable, being easily decomposed into simpler compounds.

(4)—They show many examples of isomerism.

(5)—They are often arranged in homologous series. In these series adjacent members resemble each other usually.

(6)—They occur in nature only as the result of animal or vegetable life.

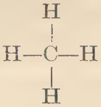
They are divided into two great groups, the fatty series, the starting point of which is methane, CH_4, and the aromatic series, which begins with benzol, C_6H_6. Besides these there are some other groups and a great number of compounds which are as yet unclassified.

The subject of Organic Chemistry is so inexhaustible that it has been necessary to go over it very briefly in this manual. Consequently only those points of great importance have been touched.

CLASSIFICATION OF ORGANIC COMPOUNDS.

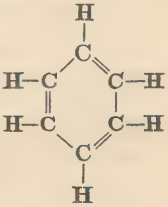
The grouping of organic compounds is based upon the negative radical instead of the positive radical as in Inorganic Chemistry. They are classified under the following heads:

(1)—*Hydrocarbon*—composed of H and C only ; thus,

Methane, CH_4, 

$$H-\overset{\displaystyle H}{\underset{\displaystyle H}{\overset{|}{\underset{|}{C}}}}-H$$

: benzol, C_6H_6,



The following is a list of the more important hydrocarbons with their names. Notice particularly the nomenclature :

Methane CH_4	Methene CH_2			
Ethane C_2H_6	Ethene C_2H_4	Ethine C_2H_2		
Propane C_3H_8	Propene C_3H_6	Propine C_3H_4	Propone C_3H_2	
Butane C_4H_{10}	Butene or Quartene C_4H_8	Quartine C_4H_6	Quartone C_4H_4	Quartune C_4H_2
Amane C_5H_{12}	Amene or Quintene C_5H_{10}	Quintine C_5H_8	Quintone C_5H_6	Quintune C_5H_4
Sextane C_6H_{14}	Sextene C_6H_{12}	Sextine C_6H_{10}	Sextone C_6H_8	Sextune C_6H_6

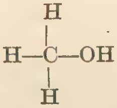
The vertical series are homologous, the horizontal are isologous. The first vertical series is called the paraffines and the second the olefines. All but the first vertical series are artiad compound radicals, though they also exist free. The names of the perissad compound radicals are formed by changing the *ane* of the first series to *yl* and in the other series by adding *yl* to the ending, thus : methyl, $(CH_3)^{i}$, propenyl, $(C_3H_5)^{iii}$, etc. Sextune, C_6H_6, is usually a saturated compound of a peculiar character, called benzene or benzol, whose graphic formula is given above. The paraffines are all saturated.

(2)—*Haloid Ether.*—A compound of a hydrocarbon radical with a halogen; corresponding to a haloid salt; thus,

$(CH_3)^{i}$ Cl, methyl chloride.
$(CH)^{iii}$ Cl_3, methenyl chloride or chloroform.

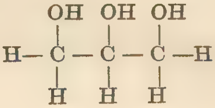
(3)—*Alcohol.*—A compound of a hydrocarbon radical with hydroxyl, OH; corresponds to an hydroxide; thus,

$(CH_3)^{i}$ OH, methyl alcohol,



$$\begin{array}{ccccc} & & H & & \\ & & | & & \\ H & - & C & - & OH \\ & & | & & \\ & & H & & \end{array}$$

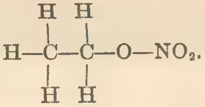
$(C_3H_5)^{iii}$ $(OH)_3$, propenyl alcohol,



$$\begin{array}{ccccccccc} & & OH & & OH & & OH & & \\ & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & \\ & & H & & H & & H & & \end{array}$$

(4)—*Compound Ether.*—A compound of a hydrocarbon radical with an oxygen-acid; corresponds to an oxygen-salt; thus,

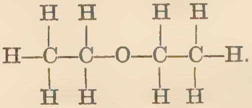
$(C_2H_5)^{i}$ NO_3, ethyl nitrate,



$$\begin{array}{ccccccccc} & & H & & H & & & & \\ & & | & & | & & & & \\ H & - & C & - & C & - & O & - & NO_2. \\ & & | & & | & & & & \\ & & H & & H & & & & \end{array}$$

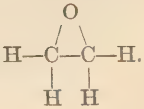
(5)—*Oxygen Ether.*—A compound of a hydrocarbon radical with O; corresponds to an oxide; thus,

$(C_2H_5)^{i}_{2}$ O, ethyl ether,



$$\begin{array}{ccccccccccccc} & & H & & H & & & & H & & H & & \\ & & | & & | & & & & | & & | & & \\ H & - & C & - & C & - & O & - & C & - & C & - & H. \\ & & | & & | & & & & | & & | & & \\ & & H & & H & & & & H & & H & & \end{array}$$

$(C_2H_4)^{ii}$ O, ethene ether or oxide,



$$\begin{array}{ccccccc} & & & O & & & \\ & & / & & \backslash & & \\ H & - & C & - & C & - & H. \\ & & | & & | & & \\ & & H & & H & & \end{array}$$

(6)—*Mercaptan.*—This is an alcohol in which the O has been replaced by S ; thus,

$(C_2H_5)^i\ SH$, ethyl mercaptan, $(C_2H_4)^{ii}\ (SH)_2$, ethene mercaptan.

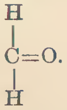
(7)—*Sulphur Ether.*—This corresponds to an oxygen ether in which the O has been replaced by S ; thus,

$(CH_3)^i{}_2\ S$, methyl sulphide.

Se and Te form compounds similarly, as in (6) and (7).

(8)—*Aldehyde.*—An alcohol, less two atoms of H, taken from the carbon-atom holding the hydroxyl group ; thus from methyl alcohol is formed formic aldehyde ;

$CH_3OH—2H=CH_2O$,

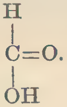


$$\begin{array}{c} H \\ | \\ C=O. \\ | \\ H \end{array}$$

This aldehyde is the starting-point of all aldehydes, and from it all the others can be obtained by substituting monad hydrocarbon radicals for one of the atoms of H. Only one H can be replaced. The other must be left connected with the C.

(9)—*Acid.*—Is an aldehyde with one atom of O added to the characteristic carbon group ; thus formic aldehyde gives formic acid :

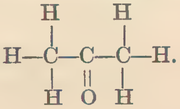
$CH_2O+O=CH_2O_2$,



$$\begin{array}{l} H \\ | \\ C=O. \\ | \\ OH \end{array}$$

(10)—*Ketone.*—Is an aldehyde in which both atoms of H have been replaced by hydrocarbon radicals ; thus,

C_3H_6O, Acetone,



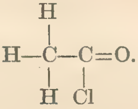
$$\begin{array}{ccccccc} & & H & & & & H & & \\ & & | & & & & | & & \\ H & — & C & — & C & — & C & — & H. \\ & & | & & \| & & | & & \\ & & H & & O & & H & & \end{array}$$

(11)—*Organo-metallic Compounds.*—Compounds of hydrocarbon radical or radicals with a metal; thus,

$(CH_3)^{i}$ K, potassium methide, $(C_2H_5)^{i}_2$ Zn, Zinc ethide.

(12)—*Acid Halide.*—Derived from an organic acid by the substitution of a halogen for hydroxyl; thus,

$(C_2H_3O)^{i}$ Cl, acetyl chloride,



$$\begin{array}{ccccc} & & H & & \\ & & | & & \\ H & — & C & — & C=O. \\ & & | & & | \\ & & H & & Cl \end{array}$$

(13)—*Acid Oxide.*—The same as in Inorganic Chemistry, the anhydride of an acid; thus,

$(C_2H_3O)^{i}_2O$, acetic oxide or anhydride.

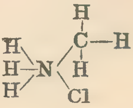
(14)—*Amine.*—Is ammonia, NH_3, in which one or more atoms of H are replaced by hydrocarbon radicals; thus,

$$(CH_3)^{i}_3\ N\text{, trimethylamine, } N\left\{\begin{array}{l} CH_3. \\ CH_3. \\ CH_3. \end{array}\right.$$

They are called primary, secondary or tertiary according as one, two or three atoms of H are replaced.

(15)—*Alcoholic Ammonium.*—Consists of NH_5 in which one or more atoms of H are replaced by hydrocarbon radicals and often inorganic radicals; thus,

NH_3ClCH_3, Methylammonium chloride.



(16)—P, As and Sb form compounds similar to (14) and (15). These are called phosphines, arsines, stibines ; phosphoniums, arsoniums, stiboniums.

(17)—*Amide.*—Is ammonia, NH_3, in which one or more atoms of H are replaced by acid radicals, *i. e.*, acids minus the the characteristic hydroxyl groups ; thus :

$(C_2H_3O)^i\ NH_2$, acetamide.

$(C_2H_3O)^i{}_2\ NH$, diacetamide.

They are called primary, secondary or tertiary according as one, two or three atoms of H are replaced.

(18)—*Amic Acid.*—Is a polybasic acid in which some, not all, of the hydroxyl groups have been replaced by NH_2, amidogen ; thus from sulphuric acid is formed

$(NH_2)^i\ HOSO_2$, sulphamic acid, $\left.\begin{matrix} NH_2 \\ HO \end{matrix}\right\} SO_2$

MONATOMIC ALCOHOLS.

There are several of importance.

CH_3OH, *Methyl Alcohol*—also called *carbinol* or wood-naphtha. It occurs largely as a by-product in the manufacture of acetic acid. *Methylated Spirit* is a mixture of methyl alcohol and ethyl alcohol. It is used extensively in England in the arts as a substitute for ethyl alcohol. Its taste is so bad that it cannot be used for drinking purposes and hence is taxed at a very much lower rate there.

C_2H_5OH, *Ethyl Alcohol*—Common Alcohol, *q. v.*

$$\left.\begin{array}{l} C_3H_7OH,\ \textit{Propyl Alcohol} \\ C_4H_9OH,\ \textit{Butyl Alcohol} \\ C_5H_{11}OH,\ \textit{Amyl Alcohol} \end{array}\right\}\ \text{constituting fusel-oil.}$$

All monatomic alcohols can be considered as carbinol in which one, two or three atoms of H have been replaced by hydrocarbon radicals. From this they are called primary, secondary or tertiary ; thus,

$(CH_3)^i\ (CH_2OH)^i$, ethyl alcohol or methyl carbinol.

$(CH_3)^i\ (C_2H_5)^i\ (CHOH)^{ii}$, secondary butyl alcohol or methyl-ethyl carbinol.

$(CH_3)^i_2\ (C_2H_5)^i\ (COH)^{iii}$, tertiary amyl alcohol or dimethyl-ethyl carbinol.

COMMON ALCOHOL.

This is simply ethyl alcohol C_2H_5OH. It can be formed synthetically thus :

$C_2+H_2=C_2H_2$, acetylene.
$C_2H_2+H_2=C_2H_4$, ethene.
$C_2H_4+H_2SO_4=C_2H_5HSO_4$, ethyl-sulphuric acid.
$C_2H_5HSO_4+H_2O=H_2SO_4+C_2H_5OH$.

The chief source of ethyl alcohol is the vinous fermentation of grape-sugar by the action of the yeast plant, the saccharomyces. The fermentation seems to be due to the efforts of this plant to obtain the food necessary for its growth. According to Prof. Chandler the requisites for fermentation are :

(1)—Glucose............	100.0	parts
(2)—Albumenoids.......	1.0	"
(3)—Mineral salts.......	0.5	"
(4)—Yeast.............	0.5	"
	102.0	

(5)—Air, at least at the outset.
(6)—A temperature between 5° and 30° C.

And the products of fermentation are :

(1)—Ethyl alcohol	48.5 parts.
(2)—Carbon dioxide	46.5 “
(3)—Glycerine	3.6 “
(4)—Succinic acid	0.7 “
(5)—Fusel oil and some extractives	0.7 “
(6)—Yeast, increased to	2.00 “
	102.0

(7)—Traces of organic compound ethers of hydrocarbon radicals which give it bouquet.

Manufacture of Beer.—Barley is moistened and allowed to germinate. During this process a ferment, diastase, is developed which converts part of the starch into sugar. The barley is now dried to prevent further growth and is called malt. The malt is crushed and placed in water at 76° C. to allow the diastase to act on the unaltered starch. It is then strained and the clear liquid, now called wort, is boiled with hops to give it a bitter flavor. It is now mixed with yeast and allowed to ferment to a certain point, but not completely. The yeast is then separated and the beer is then drawn off into casks.

Ale.—The fermentation of this takes place at a comparatively high temperature, 15°–26° C. The bubbles of carbon dioxide rise and carry the yeast to the surface, forming a thick scum. This mechanically checks the oxidation and hence the fermentation. After the ale has been drawn off into the cask, the fermentation starts up again and continues for some time.

Lager.—This is brewed at a lower temperature, 5°-10° C. The yeast sinks to the bottom and hence the fermentation is much more complete.

Manufacture of Whiskey.—This is usually made from corn, sometimes from rye, wheat, potatoes or other starch-bearing vegetables. The corn is ground and mixed with water and a very little malt. This furnishes the diastase to convert it into sugar. This mixture, called the mash, is kept at a warm temperature until all the starch has been acted on. The liquid is then drawn off and mixed with yeast. It is allowed to ferment as much as possible for it is desirable to get all the alcohol that can be obtained. It is next distilled and this gives rise to the raw whiskey. Rectification is the purification of alcohol and strong alcoholic liquors by the removal of water and fusel-oil chiefly by redistillation. Ethyl alcohol volatilizes at a lower temperature than these, and by carrying the temperature up to certain a point and not beyond, they will be left behind in the body of the still.

Wine is the fermented juice of the grape.

Brandy is the liquor obtained by distilling wine.

Rum is made from molasses by fermentation and distillation.

Gin is alcohol flavored with juniper berry and then distilled.

Ethylic Ether, $(C_2H_3)_2O$.—This is prepared from ethyl alcohol by means of sulphuric acid and hence is often called sulphuric ether. The reaction may be expressed thus :

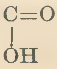
$$(1)\quad C_2H_5OH+H_2SO_4=C_2H_5HSO_4+H_2O.$$

$$(2)\quad C_2H_5HSO_4+C_2H_5OH=(C_2H_5)_2O+H_2SO_4.$$

Its specific gravity is about .720. It boils at 35.5° C. and evaporates at all temperatures. It is very combustible and its vapor may make an explosive compound with air. Its use as an anaesthetic is well known.

ACIDS OF MONATOMIC ALCOHOLS.

These are necessarily monobasic, for as there is but one alcohol-group, there can be but one acid-group. This characasteristic acid-group is $\underset{\mathrm{OH}}{\underset{|}{C}}{=}O$, a monad compound radical called



carboxyl. It is the H-atom in this group which can be replaced by metals to form salts.

The following is a list of the more important monatomic acids:

Formic	acid—	$C H_2O_2$.	Valerianic	acid—	$C_5 H_{10}O_2$.
Acetic	"	$C_2H_4O_2$.	Palmitic	"	$C_{16}H_{32}O_2$.
Propionic	"	$C_3H_6O_2$.	Stearic	"	$C_{18}H_{36}O_2$.
Butyric	"	$C_4H_8O_2$.	Oleic	"	$C_{18}H_{34}O_2$.

Formic Acid, CH_2O_2.—A clear, colorless liquid with a penetrating odor. When concentrated, it is extremely corrosive and attacks the skin energetically. It is a powerful reducing agent. It occurs in nature in the bodies of ants, some caterpillars and in stinging nettles. It gives rise to salts called formates, none of which are very important.

Acetic Acid, $C_2H_4O_2$.—This is one of the most important organic acids. It occurs in nature in the juices of some plants and animals. It is made chiefly by the slow oxidation of alcohol. One method is to allow wine or other alcohol-containing mixture to undergo the acetous fermentation. The oxidation may be much expedited by exposing the wine over a very extensive surface, especially of wood. Acetic acid is also formed during the destructive distillation of wood.

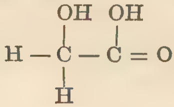
It is a thin, colorless liquid with the characteristic odor and taste of vinegar. Below 15.5° C. it forms large transparent crystals. The anhydrous acid is called officinally *Acidum Aceticum Glaciale.* This is only used externally as a mild escharotic. Its domestic use in vinegar is very extensive. It forms a number of salts called acetates. Nearly all the normal acetates are soluble and several of them are poisonous.

For the other monatomic acids reference must be made to larger works. Palmitic, stearic and oleic acids are discussed to some extent on page 107, *et seq.*

DIATOMIC ALCOHOLS.

None of these are of much importance. Those derived from the hydrocarbons of the olefine series are called glycols. Each glycol forms two acids, one monobasic and the other bibasic. Thus from *Ethene Glycol*, $C_2H_4(OH)_2$, we get

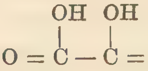
$C_2H_4O_3$, *Glycollic Acid*,



$$\mathrm{H-\underset{H}{\overset{OH}{C}}-\overset{OH}{C}=O}$$

, monobasic,

and $C_2H_2O_4$, *Oxalic Acid*,



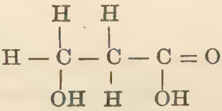
$$\mathrm{O=\overset{OH}{C}-\overset{OH}{C}=O}$$

, bibasic.

Oxalic acid and most soluble oxalates are decidedly poisonous. The antidote is any lime or magnesium salt, for these form insoluble oxalates. Treatment should be prompt for the poison is energetic.

From *Propene Glycol*, $C_3H_6(OH)_2$, are formed

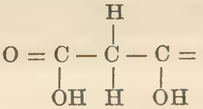
$C_3H_6O_3$, *Lactic Acid*,



$$\mathrm{H-\underset{OH}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{OH}{C}=O}$$

, monobasic,

and $C_3H_4O_4$, *Malonic Acid*,



$$\mathrm{O=\underset{OH}{C}-\underset{H}{\overset{H}{C}}-\underset{OH}{C}=O}$$

, bibasic.

Lactic acid is chiefly found in nature as a result of the fermentation of lactose and some other carbohydrates. There are several isomeric modifications of the formula, one of which is officinal under the name *Acidum Lacticum*.

TRIATOMIC ALCOHOLS.

There are only three of this class known :

$CH(OH)_3$, Methenyl Alcohol, (hypothetical).
$C_3H_5(OH)_3$, Propenyl Alcohol or Glycerine.
$C_5H_9(OH)_3$ Pentenyl Alcohol or Amyl Glycerine.

Methenyl Alcohol.

This has never been isolated, but its haloid ethers are known and are of great importance. They are:

$CHCl_3$, Methenyl Chloride or Chloroform.
CHI_3, " Iodide or Iodoform.
$CHBr_3$, " Bromide or Bromoform.

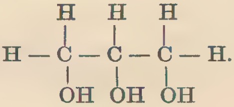
Chloroform.—This is prepared by distilling slaked lime, good commercial chloride of lime, water and alcohol together; thus,

$$2C_2H_5OH + 8CaCl_2O + Ca(OH)_2 = 5CaCl_2 + 2H_2O + 3Ca(OH)_2 + Ca(CHO_2)_2 + 2CHCl_3.$$

It is a heavy, colorless liquid, with a characteristic odor and a sweet, burning taste. Its specific gravity is 1.485. It is slightly soluble in water and mixes in all proportions with alcohol and ether. It is an antiseptic. It is extensively used as a general anaesthetic, especially in obstetrical practice. It is non-inflammable.

Propenyl Alcohol, Glycerine.

The graphic formula of this is :



$$\begin{array}{ccccccc} & & H & & H & & H & \\ & & | & & | & & | & \\ H & - & C & - & C & - & C & - H. \\ & & | & & | & & | & \\ & & OH & & OH & & OH & \end{array}$$

It is prepared by superheating stearin with water; thus,

$$C_3H_5(C_{18}H_{35}O_2)_3 + 3H_2O = C_3H_5(OH)_3 + 3HC_{18}H_{35}O_2.$$

Fats.—These are compound ethers of propenyl with the fatty acids. The most common simple fats are:

$C_2H_5(C_{18}H_{35}O_2)_3$, Propenyl Stearate or Stearin.
$C_3H_5(C_{16}H_{31}O_2)_3$, " Palmitate or Palmitin.
$C_3H_5(C_{18}H_{33}O_2)_3$, " Oleate or Olein.

Most natural fats are mixtures of these and vary in consistency according to the amount of each present. Olein is liquid at ordinary temperatures, stearin and palmitin solid when pure. The two latter when in solution in olein do not separate from it until the temperature is considerably below their usual solidifying point. Drying oils contain linoleic acid, $C_{16}H_{28}O_2$, which rapidly absorbs O from the air and becomes converted into a hard, horny film.

Soaps.—These properly consist of mixtures of the oleate, palmitate and stearate of K, which forms soft soaps, or of Na, which forms hard soaps. The term, however, is often extended to include all metallic salts of oleic, palmitic and stearic acids. These soaps are formed by the method known as saponification. This consists of the decomposition of a neutral fat by means of a hydrate or of an oxide and water; thus,

$$C_3H_5(C_{18}H_{35}O_2)_3+3KOH=3KC_{18}H_{35}O_2+C_3H_5(OH)_3.$$

The true soaps are quite soluble, but the stearates, oleates and palmitates of most of the other metals are decidedly insoluble. It is on this account that hard water does not form a lather. The calcium and magnesium salts which are in it decompose the soap, forming a lime or magnesium soap, which is insoluble; thus,

$$2NaC_{18}H_{35}O_2+CaSO_4=Ca(C_{18}H_{35}O_2)_2+Na_2SO_4.$$

Nitroglycerine.—This is simply nitrate of propenyl, $C_3H_5(NO_3)_3$. It is prepared by treating glycerine with a mixture of concentrated nitric and sulphuric acids. The latter serves to take up the water liberated; thus,

$$C_3H_5(OH)_3+3HNO_3+H_2SO_4=C_3H_5(NO_3)_3+H_2SO_4,\ 3H_2O.$$

It is a very violent explosive, there being nearly enough O to saturate all the other elements in the molecule, and the compounds thus formed are all gaseous. *Dynamite* consists of silicious infusorial earth, the interstices of which are filled with nitroglycerine. This earth is composed chiefly of the skeletons of diatoms. It will take up about three times its weight of nitroglycerine and forms a convenient way of handling this.

TETRATOMIC ALCOHOLS.

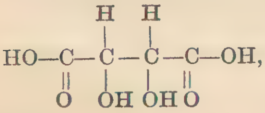
There is but one known, erythrite, $C_4H_{10}O_4$. This is of little importance, but the bibasic acid corresponding to it is very important, being

$C_4H_6O_6$, *Tartaric Acid.*—This exists in five different physical modifications. The one in ordinary use is the dextrotartaric acid, so called from its rotating polarized light to the right. It occurs in nature chiefly as potassium bitartrate or cream of tartar during the fermentation of grape-juice. It is a crystalline solid, odorless, with a distinctly acid taste, freely soluble; a bibasic acid. It forms a number of salts, among the most important being

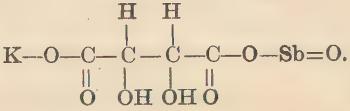
$(K)^{i}\ (Sb\,O)^{i}\ (C_4H_4O_6)^{ii}$, *Potassio-stibyl Tartrate.*—This is known officinally as *Antimonii et Potassii Tartras*, commonly as tartar-emetic. This is an acrid salt, soluble in water, decomposed by both acids and alkalies. It is prepared by boiling solutions of antimonious oxide and potassium bitartrate; thus,

$$Sb_2O_3+2KHC_4H_4O_6=2KSbOC_4H_4O_6+H_2O.$$

Tartar emetic is decidedly poisonous. The antidote is tannic acid, or any substance containing it, such as green tea. The graphic formulæ for tartaric acid and tartar-emetic are:



$$HO-\underset{\underset{O}{\|}}{C}-\overset{\overset{H}{|}}{\underset{\underset{OH}{|}}{C}}-\overset{\overset{H}{|}}{\underset{\underset{OH}{|}}{C}}-\underset{\underset{O}{\|}}{C}-OH,$$



$$K-O-\underset{\underset{O}{\|}}{C}-\overset{\overset{H}{|}}{\underset{\underset{OH}{|}}{C}}-\overset{\overset{H}{|}}{\underset{\underset{OH}{|}}{C}}-\underset{\underset{O}{\|}}{C}-O-Sb=O.$$

$C_6H_8O_7$, *Citric Acid.*—This is a tetratomic acid, the alcohol of which is unknown. It is a white, crystalline solid, freely soluble in water, occurring in nature in the juices of many fruits. It is tribasic.

There are no pentatomic alcohols known.

HEXATOMIC ALCOHOLS.

There is but one known, sextone alcohol, $C_6H_{14}O_6$. This occurs in nature in several forms, mannite, dulcite and sorbite. Mannite can be prepared artificially by acting on glucose with nascent H. It is obtained from manna, an exudation from a species of ash.

Corresponding to this alcohol, the great class of carbohydrates takes its origin. It may be subdivided into the following groups:

Glucoses.—These have a common formula, $C_6H_{12}O_6$, and may be considered aldehydes of mannite; thus,

$$C_6H_{14}O_6-H_2=C_6H_{12}O_6.$$

Nearly all rotate polarized light through different degrees, but otherwise they have very similar properties.

Saccharoses or *Sugars.*—These have a common formula, $C_{12}H_{22}O_{11}$, and may be considered as two molecules of glucose, less water; thus,

$$2C_6H_{12}O_6-H_2O=C_{12}H_{22}O_{11}.$$

Amyloses or *Starches.*—These have a formula, $C_6H_{10}O_5$, or some multiple of it, and may be considered as one or more molecules of glucose less the same number of molecules of water; thus,

$$3C_6H_{12}O_6-3H_2O=C_{18}H_{30}O_{15}.$$

Glucoses.

The two most important are dextroglucose, or dextrose, and laevoglucose, or levulose. These are so called from their power of rotating polarized light, the one to the right, the other to the left. They are usually associated in nature and can only be separated by special means. Both are found in many fruits. Dextrose alone is found in animals, while levulose does not occur separately.

Preparation.—Both may be prepared together by inverting cane-sugar by means of acids, yeast, boiling or other agents. These cause the sugar to take up a molecule of water and then split up into the two glucoses; thus

$$C_{12}H_{22}O_{11}+H_2O=C_6H_{12}O_6+C_6H_{12}O_6.$$

This is called inverting, from the fact that the effect on polarized light is changed from right-handed rotation to left-handed. Cane sugar rotates it +73.8° (to the right), dextrose +56°, levulose −106° (to the left); hence the rotation of inverted sugar is −25°; for

$$\frac{+56-106}{2}=-25.$$

This change occurs spontaneously in honey and molasses.

Dextrose alone may be prepared by the action of diastatic ferments or dilute acids on starch, causing it to take up a molecule of water; thus,

$$C_6H_{10}O_5+H_2O=C_6H_{12}O_6.$$

Levulose may be prepared alone by boiling inulin, a peculiar variety of starch, with dilute acids or for a long time with water. These cause it to take up a molecule of water.

Properties.—Both are soluble in water and alcohol, and fermentable. Both respond to the ordinary tests for glucose. Together in equal parts they are about half as sweet as cane-sugar. Dextrose is crystallizable, levulose amorphous. The latter is sweeter than dextrose, nearly as sweet as cane-sugar.

The other glucoses are of little importance.

Glucosides.—These are so called because when heated with acids, they split up into glucose and some other substance.

They are sometimes considered compound ethers of glucose. Many of the neutral principles, which are of importance on account of their medicinal value, belong to this class ; such as convolvulin, digitalin, salicin, etc. None of them are alkaloids although they may contain N.

Sugars.

Cane-sugar or *Saccharose.*—This occurs in nearly all plants, often associated with dextrose and levulose. Its chief sources are the sugar-cane, beet, maple, date, sorghum. It does not undergo the vinous fermentation directly, but it first becomes inverted and can then be fermented.

Milk-sugar or *Lactose.*—This is found in milk. It is not very sweet and is much less soluble in water than saccharose. It is more apt to undergo the lactic-acid fermentation than the alcoholic.

The other sugars are of little consequence.

Starches.

Starch.—The probable formula for this is $C_{18}H_{30}O_{15}$. It is found in every plant. It is converted into glucose by the action of a dilute mineral acid or diastase, causing it to take up one molecule of water and then split up into dextrose and dextrin ; thus,

$$C_{18}H_{30}O_{15}+H_2O=C_6H_{12}O_6+2C_6H_{10}O_5.$$

By prolonged boiling the dextrin also takes up water and becomes dextrose. Starch strikes a blue color with free I. It is insoluble in water but forms a paste with it. At high temperatures it becomes converted into dextrin, which is soluble.

Cellulose.—This is found in all plants associated with starch. Very insoluble and innutritious. By strong acids it can be converted into glucose. Gun-cotton is derived from this by the action of nitric acid, sulphuric acid being used as a dehydrator. There are three kinds, the formulæ of which are: $C_6H_7(NO_2)_3O_5$, $C_6H_8(NO_2)_2O_5$, $C_6H_9(NO_2)O_5$. The first is the explosive variety; the third when dissolved in ether and alcohol forms collodion.

Dextrin.—Its formula is $C_6H_{10}O_5$. This does not occur native. It strikes a red color with free I.

Gums.—These chemically belong to the starches but differ very much in their physical properties.

THE AROMATIC GROUP.

The starting-point of this group is C_6H_6, benzol or benzene, the graphic formula for which is given on page 97. In this formula the C-atoms are linked together alternately by single and double linkage. This makes a saturated compound of it. It would seem as if we ought to be able to break up the double links, however, and get six bonds in addition to the six already saturated with H. This has been done and additive-compounds of a formula similar to $C_6H_6Cl_6$ have been made. These additive-compounds are few and unimportant. Nearly all the compounds of this series are substitution-compounds of benzene, in which one or more H-atoms are replaced by radicals, simple or compound.

In case one H only is replaced, we get but one class of compounds. This is because all the C-atoms in the benzene-ring are symmetrical, and it makes no difference to which the replacing radical is attached.

In case two H-atoms are replaced, we get three classes of compounds, differing somewhat in their chemical and physical properties. If we number the C-atoms in the benzene-ring, 1, 2, 3, 4, 5, 6, we can attach the replacing radicals to 1 and 2, 1 and 3, or 1 and 4. In each case we get a different compound. These are the only three possible modifications, whether the two radicals are the same or not, for as all the C-atoms are symmetrical, it makes no difference at which one we begin to count.

If more than two H-atoms are replaced by different radicals the modifications become more numerous.

The aromatic compounds are less numerous and less important than those of the fatty series. Only a few of the most important can be discussed here.

C_6H_6, Benzene.—A thin, colorless, volatile liquid, with a peculiar odor; lighter than water, in which it is nearly insoluble; very inflammable. It freely dissolves I, S, P, fats, resins, etc. It is obtained almost entirely from the more volatile portions of coal-tar oil, but is also formed during the destructive distillation of many organic bodies. It can be prepared synthetically by heating ethine or acetylene, C_2H_2; thus,

$$3C_2H_2=C_6H_6.$$

From benzene most of the other hydrocarbons of this series are obtained by substituting for one or more H-atoms hydrocarbon radicals; thus,

$$C_7H_8,\ \text{Toluene},\ C_6H_5(CH_3).$$

$$C_8H_{10},\left\{\begin{array}{ll}\text{Xylene,} & C_6H_4(CH_3)_2,\\ \text{Ethylbenzene,} & C_6H_5(C_2H_5),\ \text{etc.}\end{array}\right.$$

These substituting hydrocarbon-radicals are called lateral chains. Naphthalene, $C_{10}H_8$, and Anthracene, $C_{14}H_{10}$, contain two benzene rings. In the former they are fused together, in that way losing two C-atoms and four H-atoms. In the latter they are connected by the quadrivalent radical, C_2H_2, which replaces four H-atoms.

Aromatic Alcohols.

As in the fatty series, these are formed by the substitution of hydroxyl, OH, for an atom of H. When this substitution occurs in a lateral chain, it gives rise to a primary alcohol, which resembles the primary alcohol of one of the fatty series. If the substitution occurs in the principal chain, it forms what is known as a phenol. The characteristic group of a phenol is

C-O-H, which is the same as that of the tertiary alcohols in the fatty series. They may be monatomic, diatomic, triatomic, etc., according as one, two, three or more atoms of H are replaced. They exhibit acid as well as basic properties chemically.

C_6H_5OH, *Phenol* or *Carbolic Acid.*—A colorless, crystalline solid, deliquescent. It has a characteristic odor and taste. It melts at about 100° F. By the addition of 5-10 per cent. of water it is liquefied, forming a clear solution. Beyond that point they do not mix until there is twenty times as much water as phenol, when the latter is dissolved. It is very soluble in alcohol, ether and glycerine. Commercially it generally occurs as a reddish-brown liquid from the presence of water and other impurities. It is an antiseptic, a local irritant and anæsthetic. It is poisonous ; the chemical antidotes are saccharate of lime and the soluble sulphates, especially sodium sulphate. It is known officinally as *Acidum Carbolicum.* Chemically its acid properties are very feeble and its reaction is neutral.

There are several other monatomic phenols, not of sufficient importance to be discussed

$C_6H_4(OH)_2$.—This is a diatomic phenol and consequently has three modifications. These are *Pyrocatechin*, *Resorcin* and *Hydroquinone.* Resorcin is a crystalline solid, soluble in water, alcohol and ether. It is used to some extent in medicine externally. Hydroquinone is a solid, soluble in water, alcohol and ether, not used now in medicine but used extensively as a developer in photography.

$C_6H_3(OH)_3$.—This is a triatomic phenol and there are two known modifications. These are *Pyrogallol*, commonly called pyrogallic acid, and *Phloroglucin.* The former is a soluble solid, used extensively as a developer in photography. The latter forms part of the latest and probably best test for detecting the presence of free hydrochloric acid in the gastric juice. This test is as follows : Dissolve in one oz. of absolute alcohol thirty grains of phloroglucin and fifteen of vanillin. Mix a few drops of this test solution with an equal quantity of the filtrate of the gastric contents. Evaporate in a porcelain dish with the aid of heat but without permitting any boiling. If more than 1-20 per cent. of hydrochloric acid is present, red streaks will appear in the fluid with the separation of brilliant red crystals if more than 1-10 per cent. is present. It occurs in the root-bark of several fruit-trees and is also formed by the decomposition of several tannins by means of potassa.

Amido-Derivatives.

These are formed by substituting amidogen, NH_2, for H. They resemble the amines of the fatty series. There are a number of them but only one is of sufficient importance to be described.

$C_6H_5(NH_2)$, *Phenylamine* or *Aniline.*—A colorless, oily liquid, a little heavier than water; slightly soluble in water, freely in alcohol and ether. It is a powerful base. Although colorless itself, its compounds form most of the artificial dyes used at present. It is obtained indirectly from the benzene of coal-tar.

Aromatic Acids.

The characteristic group of an organic acid is the monad radical, CO.OH, called carboxyl. The oxidation which takes place to form this group cannot affect one of the C-atoms in the principal chain of a benzene-ring for three of the bonds are already taken up by other C-atoms and the O and OH require three bonds to satisfy them. Consequently the characteristic groups in aromatic acids must occur in the side chains.

There are a great many aromatic acids, but only three can be discussed here.

$C_6H_5(CO.OH)$, *Benzoic Acid.*—A crystalline solid, sparingly soluble in water, freely in alcohol. It is found in many balsams and gum-resins. It was formerly prepared by sublimation from the balsamic resin, benzoin, and is now to some extent. It is largely obtained from hippuric acid and by synthesis from naphthalene. It forms salts, called benzoates, all of which are soluble in water. It is officinal under the name *Acidum Benzoicum.* It is a mild antiseptic and is used internally to some extent. It is excreted under the form of hippurates, hippuric acid being a compound of glycin and benzoic acid.

$C_7H_6O_5$, *Gallic Acid.*—A crystalline solid, freely soluble in hot but sparingly in cold water. It is obtained chiefly from the tannic acid in nut-galls. By the action of a ferment present there, with the aid of moisture and warmth, the tannic acid assumes a molecule of water and splits up into two molecules of gallic acid; thus,

$$C_{14}H_{10}O_9+H_2O=2C_7H_6O_5.$$

It does not precipitate albumen or salts of the alkaloids. It is used in medicine as an astringent and hæmostatic, chiefly internally under the officinal name of *Acidum Gallicum.*

$C_{14}H_{10}O_9$, *Tannic Acid.*—An amorphous solid, freely soluble in water. As was shown in the preceding paragraph, it is an anhydride of gallic acid. It precipitates albumen, gelatin and the salts of the alkaloids. It is used in medicine chiefly externally and as a chemical antidote in alkaloidal poisoning.

Under the name of tannic acid or tannin are included a number of bodies of slightly varying common composition. The one described above is the officinal *Acidum Tannicum,* known also as gallotannic or digallic acid, and obtained from nut-galls. Besides this there are a number of tannins derived from oak-bark, rhatany-root, tea, catechu, etc. These resemble digallic acid in many properties, but are incapable of conversion into gallic acid.

ALKALOIDS.

These are natural organic bases; which resemble in many of their properties the alkalies, whence their name.

Sources.—They are found native in the animal and vegetable kingdoms. They are also formed during the destructive distillation of complex organic bodies. Artificial alkaloids have been produced synthetically, resembling but not identical with the natural ones.

Composition.—Some are liquid and contain C, H and N. Most, however, are solid and contain in addition O. They belong to the amines and are usually tertiary.

Properties.—They combine with acids to form salts directly and without substitution, resembling in this ammonia, NH_3. Most of them turn red litmus-paper blue. Most of them have powerful medicinal properties and many are used in medicine.

The important native liquid alkaloids are :

Conine	from	conium maculatum,
Nicotine	"	nicotiana tabacum,
Lobeline	"	lobelia inflata,
Sparteine	"	sarothamnus scoparius.

There are many derived and artificial liquid alkaloids and the number of solid alkaloids, both native and artificial, is very great.

PROTEIDS.

Proteids or albumenoids are native nitrogenous bodies, found in animals and plants. Their empirical formula is approximately $C_{72}H_{112}N_{18}O_{22}S$. Their constitution is not known but seems to be that of a complex ureide, containing one-fifth of its N in the form of urea. They are amorphous except globin, and colloid ; they are slightly diffusible excepting the peptones which diffuse freely. Most of them are soluble in dilute acids or alkalies, but nearly all are readily coagulated. They keep well when dry, but rapidly putrefy when moist, They are all hygroscopic, and rotate polarized light to the left. They are formed almost entirely in plants. When eaten by animals and assimilated, they undergo but little alteration.

They are classified as follows :

I.—Native Albumins.	Serum-albumin. Egg-albumin. Plant-albumin.	Soluble in distilled water : coagulated by boiling.
II.—Globulins.	Globulin. Paraglobulin. Fibrinogen. Myosin. Vitellin. Globin.	Insoluble in distilled water: soluble in normal (.75%) salt solution ; coagulated by boiling.
III.—Derived Albumins.	Alkali-albumin. Acid-albumin. Casein. (?) Legumin.	Insoluble in distilled water or normal salt solution; soluble in dilute acids or alkalies, but precipitated by neutralization : not coagulated by boiling.
IV.—	Fibrin. Plant-fibrin or gluten.	Soluble in 10% solution of salt or in 0.1% of hydrochloric acid at 60° C. Converted into coagulated proteids by boiling.
V.—Coagulated Proteids.		Soluble in the gastric juice, being changed into acid-albumin or peptones. Not affected by boiling.
VI.—Peptones.		Soluble in distilled water. Not affected by boiling.
VII.—Lardacein.		Insoluble in everything but dilute ammonia. Converted by strong acids into acid-albumin and by caustic alkalies into alkali-albumen.

The tests for proteids are the same for all classes except Lardacein. They are as follows :

(1)—They are all precipitated by excess of alcohol and in time coagulated.

(2)—Xanthoproteic test. Heated with strong nitric acid, the solution turns yellow. On the addition of ammonia, soda or potassa, this becomes orange.

(3)—Mix with a strong solution of soda or potassa and add a drop of a solution of cupric sulphate. A rich purple color is developed. If chiefly peptomes are present, the color is pink.

(4)—With Millon's reagent they give a white precipitate which turns red on boiling. This reagent is prepared by dissolving pure Hg in an equal weight of nitric acid by the aid of heat. Then add twice the bulk of water, and after subsidence, decant the supernatant liquid, which is the reagent.

FERMENTATION.

Fermentation is the change or decomposition which takes place in most vegetable or animal substances after death when exposed at ordinary temperatures to air and moisture. When the process is accompanied by the liberation of fetid gases, it is termed putrefaction.

The most important varieties of fermentation are :

1—Vinous or Alcoholic	transforms	glucose	into	alcohol.
2—Acetous—	"	alcohol	"	acetic acid.
3—Lactous—	"	lactose	"	lactic acid.
4—Butyrous—	"	lactic acid	"	butyric acid.
5—Mucous or Viscous	"	cane-sugar	"	mannite and gum.
6—Saccharous—	"	starch	"	glucose and dextrin.
7—Glucosic—	"	cane-sugar	"	glucose.
8—Urinous—	"	urea	"	ammonium carbonate.
9—Peptous—	"	proteids	"	peptones.

Ferments may be divided into two classes :

(1)—*Organized*—These are composed of living organisms, usually yeasts or bacteria. These grow and multiply at the expense of the substance in which they exist. It is due to their vital activity that the fermentation occurs, the products of fermentation being probably simply their excreta.

(2)—*Unorganized*—These are produced by living cells but are themselves non-living. They seem to be of nitrogenous composition. Their mode of action is unknown except that they themselves do not seem to be affected by the transformation. They are mostly hydrolytic in their action.

The more common methods for the prevention of fermentation are as follows:

1—Thorough drying.
2—Cooling or freezing.
3—Canning, i. e., subjecting the material to a temperature sufficient to destroy the vitality of the germs, and then hermetically sealing.
4—By the use of various antiseptics, such as sodium chloride, potassium nitrate, sugar, alcohol, smoke, etc.

CHAPTER X.

TESTS.

In this chapter are given brief tests for the more important acids and metals and the principal alkaloids. Those especially which have marked poisonous properties have been mentioned. A few of them have already been described in Chap. IV.

ACIDS AND THEIR COMPOUNDS.

Nitrous Acid and *Nitrites*.........See page 34, section (7).

Nitric Acid and *Nitrates*....... .. " " " " (8).

Hydrochloric Acid and *Chlorides*.. " " " " (5).

Sulphuric Acid and *Sulphates*..... " " " " (6).

Barium nitrate, $Ba(NO_3)_2$, may be used instead of barium chloride. The barium sulphate formed in either case is characterized by its insolubility in everything but boiling sulphuric acid, and only sparingly in that.

Carbonic Acid and *Carbonates*...See page 36, section (13).

In case the carbon dioxide is combined with bases to form carbonates, it must be released from these by the addition of some stronger acid, such as hydrochloric or sulphuric.

Ortho-phosphoric Acid and *Ortho-phosphates.*

All other phosphorus compounds must first be reduced to this condition by fusion with a carbonate of an alkali and potassium nitrate. Add to the phosphoric acid, or the phosphate dissolved in nitric acid, an excess of a solution of ammonium molybdate, $(NH_4)_2MoO_4$, in dilute nitric acid and apply heat. A yellow precipitate is formed of phosphomolybdate of ammonium. Arsenic acid if present is precipitated at the same time. It should first be removed by hydrogen sulphide. In cases of poisoning it may be necessary to test directly for

Phosphorus.—This can be done by distilling the viscera with water from a glass flask connected with a glass Liebig's condenser in a dark room. At some stage in the distillation the vapor in the condenser will become phosphorescent. Should this fail it will be because the P has become oxidized. In that case it will be necessary to test for phosphorous acid, for the presence of phosphoric acid would be valueless on account of its abundance in normal tissues.

Phosphorous Acid.—The mass of viscera should be treated in a gas apparatus with zinc and hydrochloric acid. If the hydrogen-gas thus generated is contaminated with phosphoretted hydrogen, its flame will exhibit a green core, especially when depressed by a porcelain plate. This reaction will also be given by hypophosphorous acid and its salts, some of which are used medicinally.

Iodine and Iodides.

Free I strikes with starch a strong blue color. If in the form of iodides, they should first be decomposed by the addition of a little chlorine water.

Hydrocyanic Acid or *Cyanides.*

(1)—On the addition of silver nitrate a white precipitate is formed consisting of silver cyanide, AgCN. This is distinguished from silver chloride by not blackening so readily, by its solubility in boiling nitric acid, and by its being decomposed when heated in the dry state, metallic silver being left.

(2)—Add ammonium sulphhydrate and evaporate to dryness. This forms sulphocyanic acid, which, on the addition of ferric chloride or ferric sulphide, gives a blood-red color, due to sulphocyanide of iron. This color is instantly discharged on the addition of a solution of mercuric chloride or mercuric nitrate.

(3)—Add solutions of a ferrous and a ferric salt. A green precipitate is produced, which, on the addition of sulphuric acid, is changed to a deep blue precipitate, ferric ferrocyanide, $Fe_4(FeC_6N_6)_3$, the so-called Prussian blue.

METALS AND THEIR SALTS.

Potassium.

(1)—To a solution of a potassium salt, add a few drops of hydrochloric acid, platinic chloride and some alcohol. A yellow precipitate falls of potassio-platinic chloride, $PtCl_4 . 2KCl$.

(2)—Add tartaric acid and some alcohol. A white precipitate is slowly formed of potassium bitartrate, $KHC_4H_4O_6$.

(3)—Spectral examination is perfectly conclusive. See page 59.

Sodium.

There is no good precipitant for sodium salts. They all give an intense yellow color to a colorless flame and the spectroscopic test is easy and perrectly reliable. See page 62.

Ammonium.

See page 34, section (9).

Calcium.

See page 35, section (11). The crystals of calcium oxalate are easily recognized under the microscope, occurring in well-marked octahedra. The precipitate is not dissolved by acetic acid or by very dilute hydrochloric acid, but is by any excess of hydrochloric acid.

Barium.

(1)—The addition of sulphuric acid or a soluble sulphate gives a dense white precipitate of barium sulphate, $BaSO_4$, soluble only in boiling sulphuric acid and sparingly in that.

(2)—Hydrofluosilic acid gives a white precipitate.

Magnesium.

See page 35, section (12).

Zinc.

Ammonium sulphide causes a dense, white precipitate of zinc sulphide, insoluble in caustic alkalies.

Lead.

(1)—Sulphuretted hydrogen or ammonium sulphide gives a black precipitate of lead sulphide, PbS.

(2)—Sulphuric acid or a soluble sulphate gives a white precipitate of lead sulphate, $PbSO_4$, insoluble in nitric acid.

(3)—Hydrochloric acid or a soluble chloride gives a white precipitate of lead chloride, $PbCl_2$. This may be entirely dissolved by great excess of water, especially boiling, and does not form if the lead salt is in very dilute solution.

(4)—Alkalies or their carbonates give white precipitates. With the former, it consists of lead hydrate, $Pb(OH)_2$, soluble in excess of water, except when produced by ammonia. With the latter, it consists of lead carbonate, $PbCO_3$, insoluble in excess of pure water.

(5)—Potassium iodide gives a yellow precipitate of lead iodide, $Pb\,I_2$.

(6)—Potassium chromate gives a precipitate of lead chromate, $Pb\,Cr\,O_4$.

Copper.

(1)—Sulphuretted hydrogen or ammonium sulphide gives a black precipitate of cupric sulphide, CuS.

(2)—Sodium or potassium hydrate gives a blue precipitate of of cupric hydrate, $Cu(OH)_2$. By boiling this is converted into the brown cupric oxide, CuO.

(3)—Ammonium hydrate in excess gives a dark-blue color.

(4)—Potassium ferrocyanide gives a reddish-brown precipitate of cupric ferrocyanide, $Cu_2FeC_6N_6$.

(5)—Immerse a bright piece of steel in an acidulated solution. Metallic Cu is immediately precipitated on it.

Mercury.

(1)—Stannous chloride produces a white precipitate, which on heating becomes dark-gray. This consists of metallic Hg.

(2)—Place a piece of bright metallic Cu in a slightly acid solution of a mercury salt, but one not containing any free nitric acid. The Cu becomes covered with a dark gray film of metallic Hg. This can then be separated by volatilization and condensation.

Mercurous Salts.

(1)—Sulphuretted hydrogen or ammonium sulphide gives a black precipitate of mercurous sulphide, Hg_2S.

(2)—Potassium iodide gives a green precipitate of mercurous iodide, Hg_2I_2.

(3)—Potassium, sodium or calcium hydrate gives a very dark precipitate of mercurous oxide, Hg_2O.

(4)—The alkaline carbonates give a white precipitate of mercurous carbonate, Hg_2CO_3, soon decomposing into the black mercurous oxide.

(5)—Hydrochloric acid or a soluble chloride gives a white precipitate of mercurous chloride, Hg_2Cl_2. This turns black on the addition of ammonia.

Mercuric Salts.

(1)—Sulphuretted hydrogen orammoniumsulphide gives, if in excess, a black precipitate of mercuric sulphide, HgS. This on sublimation becomes red.

(2)—Potassium iodide gives a red precipitate of mercuric iodide,

HgI_2, soluble in excess of either the mercuric salt or the potassium iodide.

(3)—Potassium, sodium or calcium hydrate gives a yellow precipitate of mercuric oxide, HgO.

(4)—The alkaline carbonates give a yellowish-brown precipitate of mercuric carbonate, $HgCO_3$. This is very unstable.

(5)—They give no precipitate with hydrochloric acid or soluble chlorides.

Silver.

Hydrochloric acid or a soluble chloride gives a dense white precipitate of silver chloride, $AgCl$, which blackens on exposure to light, is insoluble in hot nitric acid but is completely dissolved by ammonium hydrate, from which it is precipitated on neutralization by nitric acid. It is distinguished from lead chloride by its insolubility in water, the latter being dissolved by excess of boiling water. From mercurous chloride, it is distinguished by the latter being instantly blackened by ammonia.

Aluminium.

(1)—On the addition of sodium or potassium hydrate a white gelatinous precipitate of aluminium hydrate, $Al(OH)_3$, is produced, soluble in excess of the alkali. Ammonium hydrate gives the same precipitate, but it is insoluble in in excess of ammonia.

(2)—The carbonates of ammonium, K and Na, give the same precipitate with the liberation of carbon dioxide.

(3)—Ammonium sulphide gives the same precipitate with the liberation of sulphuretted hydrogen.

Iron.

Ferrous Salts.

(1)—Ammonium sulphide gives a black precipitate of ferrous sulphide, FeS.

(2)—Sulphuretted hydrogen gives no reaction.

(3)—Hydrates of ammonium, Na or K, give a white precipitate of ferrous hydrate, $Fe(OH)_2$. This soon turns green and then brown from absorption of O.

(4)—Carbonates of ammonium, K or Na, give a white precipitate of ferrous carbonate, $FeCO_3$, soon turning darker.

(5)—Potassium ferrocyanide gives an almost white precipitate of ferrous ferrocyanide, $Fe_2FeC_6N_6$, soon turning blue.

(6)—Tannic acid gives no reaction.

Ferric Salts.

(1)—Ammonium sulphide gives a black precipitate of ferrous sulphide mixed with S.

(2)—Sulphuretted hydrogen gives a white precipitate of S and converts them into ferrous salts.

(3)—Hydrates of ammonium, Na or K, give a reddish-brown precipitate of ferric hydrate, $Fe_2(OH)_6$.

(4)—Carbonates of ammonium, Na or K, give the same precipitate as in (3) with the liberation of carbon dioxide.

(5)—Potassium ferrocyanide gives a dark-blue precipitate of ferric ferrocyanide, $Fe_4(FeC_6N_6)_3$, commonly called Prussian blue.

(6)—Tannic acid gives a dark greenish-black precipitate of ferric tannate.

Manganese.

(1)—Ammonium sulphide gives a flesh-colored precipitate of manganous sulphide, MnS, soluble in acetic or mineral acid.

(2)—Hydrates of ammonium, K or Na, give a white precipitate of manganous hydrate, $Mn(OH)_2$, soon becoming darker from absorption of O.

(3)—Carbonates of ammonium, K or Na, give white precipitates of manganous carbonate, $MnCO_3$.

Chromium.

Chromic Acid or *Chromates.*

(1)—Any soluble lead salt will produce a yellow precipitate of lead chromate, $PbCrO_4$, insoluble in acetic but soluble in hydrochloric acid.

(2)—Any soluble barium salt produces a pale-yellow precipitate of barium chromate, $BaCrO_4$.

(3)—Any soluble silver salt produces a dark-red precipitate of silver chromate, Ag_2CrO_4

(4)—Any soluble mercurous salt produces a red precipitate of mercurous chromate, Hg_2CrO_4.

Any compound of Cr can be converted into an alkaline chromate by ignition with a mixture of potassium nitrate and an alkaline carbonate. The above tests can then be applied.

Gold.

(1)—Ferrous sulphate gives a dark-brown precipitate of metallic gold, which can be fused.

(2)—Stannous chloride gives a brownish-purple precipitate, called "Purple of Cassius."

Bismuth.

(1)—Hydrogen sulphide gives a very dark-brown precipitate of bismuth sulphide, Br_2S_3.

(2)—The addition of water to a solution of a bismuth salt produces a white precipitate of a basic salt.

Antimony.

(1)—Hydrogen sulphide gives an orange-red precipitate of antimonious or antimonic sulphide. This is soluble in ammonium sulphide but is precipitated on neutralization with an acid.

(2)—Dissolve the sulphide thus produced, by heating with concentrated hydrochloric acid. Pour the solution into water and a white precipitate of an oxychloride forms.

(3)—For Marsh's test in relation to Sb, see page 131.

Arsenic.

(1)—When ignited, it gives a garlicky odor.

(2)—If in the form of arsenious oxide, it may be reduced to metallic As by heating it in a test-tube with sodium carbonate and charcoal. The As condenses in the cool part of the tube in the form of a black deposit.

(3)—Hydrogen sulphide in neutral or slightly acid solution gives a yellow precipitate of arsenious sulphide, As_2S_3, soluble in ammonium sulphide or an alkaline hydrate, but insoluble in dilute hydrochloric acid.

$$As_2O_3+3H_2S=As_2S_3+3H_2O.$$

(4)—Ammonio-silver nitrate gives with neutral solutions of arsenious acid a light yellow precipitate of silver arsenite; thus,

$$As_2O_3+6AgNO_3+6NH_4OH=2Ag_3AsO_3+6NH_4NO_3+3H_2O.$$

With solutions of arsenic acid it gives a reddish-brown precipitate of silver arseniate, Ag_3AsO_4. Both these precipitates are soluble in acids and alkalies. The ammonio-silver nitrate is made by adding just enough aqua ammoniae to a solution of silver nitrate to dissolve the precipitate first formed.

(5)—Ammonio-cupric sulphate (made similarly to the preceding) gives with neutral solutions of arsenious acid a bright green precipitate of cupric arsenite; thus,

$$As_2O_3+3CuSO_4+6NH_4OH=Cu_3(AsO_3)_2+3(NH_4)_2SO_4+3H_2O.$$

With solutions of arsenic salts it gives a precipitate, also green, but of cupric arseniate. These are also soluble in acids and alkalies.

(6)—Reinsch's Test. This is really a method for obtaining arsenic from solutions, especially those containing organic matters. Hydrochloric acid is added to the solution and then strips of bright metallic Cu are placed in it and the whole is boiled. Nearly the whole of the As is deposited on the Cu as a gray film, constituting an alloy. The presence of nitrates or chlorates prevents this deposit until the whole of these substances have been consumed by the action of the Cu.

(7)—Marsh's Test. This is the most reliable, especially for minute quantities. In a gas-generating apparatus are placed metallic Zn and sulphuric acid. This causes the liberation of H, which is carried through a long glass tube to a burner. There it burns with an almost colorless flame, which gives no deposit on a plate held in the flame. The suspected solution is now added. If As be present, the flame becomes larger and bluish from the formation of arseniuretted hydrogen and emits an odor of garlic. If a cold porcelain plate is held in the flame, a dark-brown spot, composed chiefly of metallic As, is deposited on it. Sb will give a very similar reaction. In order to distinguish it from As, the following points may be noticed :

a—Solution of chloride of lime (page 15) will dissolve spots of As but does not affect those of Sb.
b—Stannous chloride has no effect on spots of As, while it dissolves those of Sb slowly and completely.
c—Add a few drops of nitric acid to the spot and evaporate to dryness. The addition of a drop or two of a solution of silver nitrate will turn it bright red if it is As ; if Sb, it will remain white.
d—Pass the gass into a solution of silver nitrate. In both cases a black precipitate falls. In the case of Sb, it consists of silver antimonide, Ag_3Sb, in which all the Sb is contained ; thus,

$$H_3Sb + 3AgNO_3 = 3HNO_3 + Ag_3Sb.$$

The solution now contains no Sb, while the filtrate will give the ordinary reactions for it.

In the case of As, it will consist of metallic Ag; thus,

$$H_3As+6AgNO_3+3H_2O=H_3AsO_3+6Ag+6HNO_3.$$

Arsenious acid remains in solution and can be tested for.

(8)—Fleitmann's Test. This is simply a modification of Marsh's test, but is very convenient and easily applied. It would not suffice in a criminal case, however. In a large, long test-tube, place some small fragments of Zn and solution of sodium hydrate. This gives rise to the formation of nascent H Add the suspected liquid and place a loose wad of cotton in the tube a few inches above the level of the fluid to prevent excessive frothing. Over the mouth of the tube place a piece of bibulous paper moistened by a drop of silver nitrate solution. If As is present, arseniuretted hydrogen will be formed. This will decompose the silver nitrate with the liberation of metallic Ag, which will give a purplish-black stain. The presence of ammonia interferes with this reaction.

ALKALOIDS.

Aconitine.

Dr. Stephenson, in his testimony in the Lamson murder case, considered the physiological test to be the best and it was accepted by the Court as sufficient legal evidence. It consists in the development of a peculiar tingling numbness in the tongue and back of throat after taking the alkaloid, lasting for some time.

Atropine.

(1)—The best test is physiological, done by dropping a little of the suspected fluid in a cat's eye and noting the mydriasis. In case of poisoning, the urine can be used for this, Cocaine, unless in sufficient strength to cause anæsthesia. will not produce this effect.

(2)—Add a solution of atropine to a hot mixture of sulphuric acid and potassium bichromate. A pleasant, aromatic odor is developed.

Hyoscyamine. Hyoscine.

These are isomeric with atropine. Test (1) for atropine is also the best for them. Hyoscyamine can be distinguished from atropine by the following means: On the addition of a solution of auric chloride, in both cases a precipitate is formed which can be dissolved in boiling water acidulated with hydrochloric acid. From this it is deposited, if it contains hyoscyamine, in the form of brilliant, golden-yellow scales; if atropine, in the form of minute crystals, forming a dull lustreless powder on drying. The so-called daturine is simply a mixture of atropine and hyoscyamine.

Caffeine.

Treat it with concentrated nitric acid. Evaporation leaves a yellow mass, which on the addition of aqua ammoniae becomes purple.

Conine.

(1)—Heated with concentrated sulphuric acid, it becomes brown, blood-red and then black.

(2)—Its odor is peculiar, resembling that of the urine of mice. This may be intensified by rubbing it with potassa.

Gelsemine.

Strong sulphuric acid produces a reddish color, which when moderately heated, becomes purple.

Eserine or *Physostigmine.*

(1)—An aqueous solution of the alkaloid or of one of its salts, if exposed to the air in the presence of potassium, sodium or calcium hydrate, turns red, gradually changing to yellow, green or blue.

(1)—The physiological test consists in applying a little of the solution to the eye and noting the myosis.

Morphine.

Add to the solution a few drops of a strong neutral solution of ferric chloride and then a few drops of a solution of potassium ferricyanide. A color is developed, varying from a deep blue to a pale blue, according to the amount of alkaloid present. A very delicate test, but an excess of alkali interferes and it is prevented by acids.

Codeine.

If dissolved in sulphuric acid containing 1 per cent. of sodium molybdate, it forms a solution having a dirty-green color which after a while becomes pure blue, and in a few hours fades to a pale yellow.

Narcotine.

Concentrated sulphuric acid forms with it a solution which soon becomes yellow, and on heating, purple.

Nicotine.

(1)—Becomes violet on warming with hydrochloric acid.
(2)—Developes an orange-red color on the addition of nitric acid.

Pilocarpine.

The physiological test consists in applying a solution of it to the eye and noting the myosis. In this it resembles eserine but it could be distinguished from that alkaloid by the other test given under it.

Quinine.

Add to the solution chlorine-water and then aqua ammoniæ. A clear emerald-green color results, sometimes a green precipitate.

Strychnine.

(1)—Add to a few drops of cold concentrated sulphuric acid, a drop of the solution and then a small crystal of potassium bichromate, or of ceroso-ceric oxide. A deep blue color is developed, which rapidly becomes violet and then cherry-red. The latter color is permanent if ceroso-ceric oxide is used.

(2)—Another good test is the physiological, done by injecting a little of the solution, or of the urine in case of poisoning, into a small frog. This is then placed in water, in which its convulsive movements can be readily noticed.

Brucine can be distinguished from strychnine by the intense crimson color which is developed on the addition of concentrated nitric acid. This gives no color with strychnine.

Veratrine.

The officinal *Veratrina* is probably a mixture of several alkaloids. If mixed with concentrated sulphuric acid, it develops first a yellow color, soon becoming reddish-yellow, intense scarlet, and finally violet-red.

Digitalin.

This is doubtless a mixture of alkaloids. No satisfactory chemical test could be found. In one case of poisoning by this drug, which occurred in France, the physiological test of its action on the heart was accepted as sufficient proof of its nature.

CHAPTER XI.

THE URINE.

The urine is the chief watery excretion of the body, containing also the major portion of the nitrogenous and inorganic excreta. Its specific gravity varies from 1015 to 1025 in health ; it may have temporary extremes of 1002 or 1040, without indicating necessarily disease. Its color varies from pale-yellow to amber. It has a characteristic odor and salty taste. Its reaction is acid in man and carnivora, but alkaline in herbivora. It may be alkaline or neutral in man in health. This acid reaction is due chiefly to the monosodic orthophosphate, but also to the acid urates and hippurates.

Fermentations.—These are two in number :

(1)—*Acid.*—This occurs only in acid urine, within a few hours after it has been passed. Its cause is not well understood. It gives rise to increased acidity and a deposit of uric acid, urates and calcium oxalate.

(2)—*Alkaline.*—This occurs subsequent to the acid fermentation. It may occur within the bladder in disease. It is due to the micrococus ureæ and bacterium ureæ, which cause the urea to assume two molecules of water and become changed into ammonium carbonate. This causes a precipitation of the earthy phosphates, ammonio-magnesium phosphate and acid ammonium urate.

Composition.

	Water	950.
Organic.	Urea	26.
	Uric acid and urates	1.4
	Hippuric acid and hippurates	0.7
	Kreatinine, xanthine, hypoxanthine	0.8
	Taurin, cystin, mucus, pigment	0.35
Inorganic.	Disodic and dipotassic orthophosphates	3.3
	Monosodic orthophosphate	0.4
	Calcium and magnesium orthophosphate	0.8
	Sodium and potassium chlorides	12.55
	Sodium and potassium sulphates	3.3
	Gases, (N and carbon dioxide)	
		999.60

UREA, $(NH_2)_2CO$.—The chemical characters of this have already been described on page 65. It is a crystalline solid, freely soluble in water and alcohol, insoluble in ether.

Test.—By means of sodium hypobromite or sodium hypochlorite, the urea is decomposed into sodium bromide or chloride, carbon dioxide, water and N. The latter is collected by displacement and measured. 0.1 gm. of urea forms 30.3 c. c. of N at the ordinary temperature and pressure.

URIC ACID, $C_5H_4N_4O_3$.—A colorless, crystalline solid, almost insoluble in water. It forms fairly soluble salts with the alkalies. Its constitution is doubtful, but it is either a cyanogen compound or an amide, possibly both. It is intimately related to urea, and when decomposed, that is usually one of the products. It is very abundant in the urine of birds and reptiles, but entirely absent from that of herbivora.

Test.—Evaporate the uric acid or urate slowly with nitric acid. Allow the yellowish-red stain thus produced to cool. On adding a drop of ammonia, a purplish-red color is obtained. This is called the murexide test.

HIPPURIC ACID, $C_9H_9NO_3$.—The proper chemical name for this is benzoylamidoacetic acid. It is formed by the conjugation of benzoic acid and glycin or amido-acetic acid ; thus,

$$C_7H_6O_2+C_2H_5NO_2=C_9H_9NO_3+H_2O.$$

It is almost absent in the urine of carnivora, but replaces uric acid in that of herbivora. It is a colorless, crystalline solid, sparingly soluble in water.

CREATININ, XANTHIN AND SARKIN OR HYPOXANTHIN.—These are crystallizable nitrogenous bodies, occurring in small quantities in the urine. They are complex ureides, having a close relationship to uric acid.

The inorganic constituents of the urine are described, each under its proper element.

ABNORMAL CONSTITUENTS.

ALBUMIN.—This is the most important proteid found in the urine, although paraglobulin often accompanies it, and occasionally the derived albumins. The following are the more reliable tests for it:

(1)—Fill an ordinary test-tube nearly full with urine. Unless this is distinctly acid, add a few drops of acetic acid until it is. Boil the upper part of the liquid in the tube. If albumin is present, it will form a white precipitate, varying in thickness according to the amount of albumin present. This precipitate may be due to the earthy phosphates. If it is, the addition of a few drops of nitric acid will cause it to disappear, while it only intensifies that due to albumin.

(2)—Heller's test. Fill a test-tube with urine for 1—2 inches. Allow nitric acid to run gently down the side of the tube, or introduce it near the bottom by means of a long pipette. The nitric acid, owing to its greater specific gravity, sinks to the bottom. If albumin is present, between the two fluids appears in a few moments a clear distinct white band, varying in thickness and intensity according to the amount of albumin present. Urates also give a white band, but this is less defined and more diffused. It occurs higher in the urine and is dissipated on warming. This test is much less delicate than (1).

(3)—Picric acid. Pour a saturated solution of picric acid, containing a little citric acid, on 3—4 inches of urine in a test-tube. If albumin is present, an opacity is produced at the junction of the two fluids, which is increased on heating. Urates, peptones, quinine, morphine and other vegetable alkaloids give a similar turbidity, but this disappears on the application of heat. According to Stewart, this is twice as delicate as (1). It is less reliable.

(4)—No very accurate and convenient method of estimating the quantity of albumen has yet been devised. A simple method and one fairly accurate for comparative observation is as follows: Use a graduated test-tube, filled each time to the same point, and precipitate the albumen by means of (1). Let it stand for 24 hours and then note the quantity of precipitate. This gives but a vague idea of the actual amount of anhydrous albumin present, but it indicates very fairly the comparative amount from day to day in an individual case.

A number of other tests are used, but these are the best and most convenient.

PEPTONES.—These occur chiefly as peptone proper, but occasionally as pro-peptone. The following is a good test: Precipitate the albumin as in test (1), page 138, and filter. Add a solution of soda or potassa to the filtrate until strongly alkaline. Then a trace of cupric sulphate develops a pink color if peptones are present. This is called the biuret reaction.

SUGAR.—Inosite, levulose and lactose have been noticed in the urine, but the only carbohydrate of importance found there is dextrose, called commonly glucose. For its characters see page 110. The tests used for it are very numerous. Most of them depend upon its reducing power, which is marked, and hence other reducing agents, especially uric acid and urates, may give the same reactions. Only a few of the best can be given.

(1)—Nylander's test. Dissolve 2 gm. of bismuth subnitrate and 4 gm. of Rochelle salt in 100 c. c. of 8 per cent. solution of sodium hydrate. Mix equal parts of the reagent and the urine in a test-tube and boil the upper layers for several minutes. If sugar is present, a black precipitate of metallic Bi is formed. Nylander's is not so apt to be affected as Fehling's solution by other reducing agents.

(2)—Fehling's Test. This is an alkaline solution of potassio-cupric tartrate, composed as follows:

Cupric sulphate.......	69.28	grammes.
Rochelle salt..........	250.	"
Caustic soda...........	100.	"
Water, up to..........	2	litres.

Each c. c. of this mixtures represents .005 grammes of anhydrous dextrose and will be decolorized by that. It is best to keep it in two solutions, one containing the cupric sulphate in 1 litre of water, and the other containing the Rochelle salt and soda in the other litre of water. Mix equal quantities at the moment of using. Put about 1 c. c. of the reagent with 3 or 4 of water in a test-tube and boil. This is to determine if the reagent has become decomposed. If no precipitate occurs, add the urine drop by drop, boiling at intervals. If sugar is present, a yellow or red precipitate of cuprous oxide is produced. This test may be used quantitatively by noting the amount of urine it takes to decolorize 20 c. c. of the reagent. This represents .1 gramme of dextrose.

(3)—Fermentation Test.—This depends upon the conversion of dextrose into carbon dioxide and alcohol through the action of the yeast plant (see page 102). Place about 100 c. c. of the urine in a loosely corked bottle with a small lump of yeast. Put the bottle in a warm place. After twenty-four hours, note the specific gravity of the urine and that of a control specimen kept in a cool place. Any loss will indicate the presence of sugar. The quantity is approximately indicated by the number of degrees lost, each degree representing one grain of dextrose per ounce.

There are a large number of other tests used but these are sufficient and satisfactory.

BILE.—This may occur in the urine in the form of the bile-salts or bile-pigments or both. If the bile-pigments are present, the urine is colored a smoky reddish-brown color. The best test for them is

(1)—Gmelin's Test.—In a test-tube put 2—4 c. c. of the urine. Let 1—2 c. c. of nitroso-nitric acid run down the side of the tube and rest on the bottom, floating up the urine on top. A play of colors is produced between the two fluids, beginning above with the brownish urine and running through green, blue, violet, red and yellow.

(2)—For the bile-salts, Pettenkofer's test is classical but of no practical value on account of the difficulty of application. Hays test*, if time proves its reliability, will be very satisfactory on account of the ease with which it can be done and its extreme delicacy. It depends upon the fact that the bile-salts lower the surface-tension of the liquid in which they are dissolved. It is done by sprinkling some powdered sulphur on the surface of the liquid and noting how soon it sinks. In normal urine it will remain on the surface for a week or longer. If the bile-salts are present in the proportion of 1 to 120,000, the sulphur will sink, though very slowly. In the proportion of 1 to 10,000 it will be precipitated in a few minutes.

For the other abnormal constituents of the urine, the special works of reference on this subject must be consulted.

---

* Landois and Stirling's Physiology, 2d Edit., page 294.

CHAPTER XII.

CHEMICAL THEORIES.

THE ATOMIC THEORY.

In the beginning of this century, Dalton announced two laws governing chemical compounds which are as follows :

1—*The law of Definite Proportions.*

Every chemical compound always contains the same constituents in the same proportion by weight.

2—*The Law of Multiple Proportions.*

If two substances, A and B, form several compounds with each other and we consider any fixed weight of A, then the different weights of B, which combine with this fixed weight of A, bear a single ratio with each other.

These laws have been confirmed by all investigations since his time. The first one requires no explanation, but the Law of Multiple Proportions is more obscure. Let us consider the oxides of nitrogen. There are five of these. If we analyze them we find each of them contains 28 parts, by weight, of nitrogen. Of oxygen the first one contains 16 parts by weight, the second 32, the third 48, the fourth 64, and the fifth 80. If we examine these weights of oxygen we find they bear the simple relation of 1, 2, 3, 4 and 5.

Upon these two laws is founded the atomic theory. In this theory all matter is supposed to be composed of minute indivisible atoms. These atoms entire enter into chemical combination. The atoms of each element have a fixed weight, known as the atomic weight of that element. As we are not able to weigh them directly nor to express their weight in terms referable to the earth's mass, we assign them comparative weights, the standard being the lightest substance known, hydrogen. This is taken as unity.

These atoms do not exist free but are held together by chemical affinity to form molecules. This is as true of elementary as of compound bodies with three exceptions. These are cadmum, mercury and zinc, whose atoms do not unite with each other when the element is in the gaseous state. Under ordinary circumstances the atoms of all the other elements form molecules composed of two atoms each, with two exceptions. These are phosphorus and arsenic, whose molecules are composed of four atoms each.

The determination of these atomic weights is often a matter of great difficulty. We can readily find the percentage composition of a compound, but it is yet hard to decide how many atoms of each element compose it. The methods are briefly as follows :

(1)—Take the simplest case, that of hydrochloric acid. The proportion of H is 1, of Cl is 35.5. We are able by chemical means to displace the whole of the H and only the whole, not one-half or any other part ; similarly with the Cl. We therefore conclude that they are united atom to atom. Taking the atomic weight of H as unity, then that of Cl will be 35.5. We find a similar compound of Na and Cl. This contains 35.5 parts of Cl and 23 of Na. Hence we conclude that the atomic weight of Na is 23. This method is only applicable to a few elements.

(2)—*By substitution.*—The composition of methane is 3 parts of C to 1 of H. We can act upon methane with Cl four successive times ; each time the same amount of H will be displaced by the same amount of Cl, and each time a new compound will be found. We can only do this four times, and hence we conclude that methane contains four atoms of H. That being the case, the atomic weight of C must be 12. This is only applicable to a few elements.

(3)—*Avogadro's Law.*—This is a hypothetical statement, based upon the physical properties of gases. It is as follows .

All gases under similar circumstances contain the same number of molecules in the same volume.

It is borne out by all facts, physical and chemical, and we can accept it as proved. As a result of this law, it must be held that the ratio of the molecular weights of all gases to their specific gravities is the same. For the molecular weight is simply the comparative weight of the molecules of the element and of the standard, and the specific gravity is the comparative weight of equal volumes of the gas and the standard. If the molecules of one gas weigh twice as much as those of another, then if this law is correct, its specific gravity will also be twice as great. But that will make the ratio the same in both cases, q. e. d.

Take H as an example. Its specific gravity compared to air is .06826, and its molecular weight of course is 2. for it is the standard. The ratio is 28.88 and this number represents the ratio of the molecular weight of each and every element to its specific gravity. Representing the molecular weight by w and the specific gravity by d, then

$$w=d\times 28.88.$$

This is only applicable to a few elements directly, as but few can be converted into gases. A large number of compounds, however, can be used, and from these the atomic weights of many other elements have been determined.

(4)—*Specific Heat.*—This is the amount of heat necessary to raise a given weight of a substance 1° C. as compared with the amount necessary to raise the same weight of the standard, water, 1° C. Dulong and Petit discovered the following law in relation to it:

The product of the atomic weight of an element by its specific heat is always a constant quantity: or *The atoms of all elements have exactly the same capacity for heat.*

Thus the atomic weight of As is 75 and its specific heat is .0814. The ratio of these two numbers is 6.1. If the preceding law is correct, this ratio, called the atomic heat, is constant for all elements. Hence it is only necessary to determine it once. Having it, we can easily calculate the atomic weight if we know the specific heat. For if we designate the atomic weight by A and the specific heat by H, then

$$A = \frac{6.1}{H}$$

This method is especially applicable to solids.

(5)—*Isomorphism.*—This is not of much value but occasionally proves of service. Thus the only oxide of Al contains 54 parts by weight of Al and 48 of O. This gives us no clue as to the number of atoms of each present. We find however that it is isomorphous with ferric oxide and also forms many salts isomorphous with those of ferric oxide. Also a crystal of aluminium-alum will grow perfectly well in a solution of iron-alum. We know the composition of ferric oxide to be Fe_2O_3 and thence we infer that of aluminium oxide to be Al_2O_3. That being the case, it gives an atomic weight to Al of 27, and to O of 16.

VALENCE.

By the term *valence* or *atomicity* is meant the saturating power of an element. It has already been discussed to some extent in Chapter VII. There it must be noticed that the number of bonds which an element possesses, varies when in combination, even with the same element. Compare the various acids of S given. In hydrosulphuric it is dyad, in sulphurous tetrad, in sulphuric hexad. This varying valence of elements is one of the most puzzling facts to account for. All the elements partake of it unless we except H, which always seems to be univalent. The valence decreases with the increase of temperature. Thus phosphorus pentachloride, PCl_5, when heated to a point sufficient to vaporize it, is decomposed into PCl_3 and Cl_2. This is also true of ammonium chloride, NH_4Cl, which breaks up int NH_3 and HCl. When these are lowered to the ordinary temperature, they unite again, forming PCl_5 or NH_4 Cl. There have been many suppositions offered to explain this varying valence. Among the best are the following:

(1)—It has been suggested that all the combining bonds of an element are not of the same character, and some even number of them are feebler than the others. If this were the case, it should occasion some physical differences in a single compound, such as NH_4Cl, whether the Cl was attached to an ordinary bond or to one of the weaker ones. This is certainly not the case in most elements. In the case of N and S, it seems more plausible.

(2)—It may be that all of the bonds are of the same kind, but that the total affinity is the same. In that case the compounds having fewer molecules would be the more stable, providing the total affinity was saturated. For to spread the total affinity over five bonds for example, would make each one weaker than when it was spread over three only.

(3)—It has been suggested that the bonds of an element may saturate each other, in that way neutralizing each other. This seems plausible, for with very few exceptions, the valence varies by an even number of bonds.

(4)—In some compounds it seems to be that atoms of the same element may aid in saturating each other. Thus hydrogen peroxide can be written H—O—O—H. This is apparently the case in the mercury, copper and aluminium compounds as shown on page 56.

CHEMICAL AFFINITY.

The nature of this is very imperfectly known. It is to some extent comparative, for an element often has a marked affinity for some and none at all for others. Thus H combines energetically with Cl but not at all with Cr; F unites readily with Si but not at all with O.

It does not depend at all upon the number of bonds an element possesses. Cl, which is a monad, has a more powerful affinity for H than C, which is a tetrad. Nor does it depend on the basicity of an acid, for according to Remsen hydrochloric and nitric acids, which are monobasic, have a much greater avidity for combination than sulphuric, which is bibasic, or hydrofluoric, which is also monobasic. This avidity of elements and acids however is often disturbed by two circumstances.

(1)—If by the union of liquids or solids a gas can be formed, this will happen usually, irrespective of the affinities of the different elements. Thus if we add sulphuric acid to a nitrate or chlorate and apply heat, the sulphuric acid will displace those acids although weaker than they. For they are gases and volatilize as fast as formed.

(2)—If by the union of liquids or of substances in solution, a solid or an insoluble substance can be produced, this will usually occur. Cl has a greater affinity for Na than for Pb. But if we add a soluble lead-salt to a solution of sodium chloride, a precipitate of lead chloride is formed owing to its solubility being much less than either of the others.

TABLE OF METRIC WEIGHTS AND MEASURES.

Measures of Length.

1 millimeter = 0.001 meter = 0.0394 inch.
1 centimeter = 0.01 meter = 0.3937 inch.
1 decimeter = 0.1 meter = 3.9371 inches.
1 meter = 39.3708 inches.
1 decameter = 10 meters = 32.8089 feet.
1 hectometer = 100 meters = 328.089 feet.
1 kilometer = 1000 meters = 0.6214 mile.

Measures of capacity.

1 milliliter = 1 c.c. = 0.001 liter = 0.0021 U. S. pint.
1 centiliter = 10 c.c. = 0.01 liter = 0.0211 U. S. pint.
1 deciliter = 100 c.c. = 0.1 liter = 0.2113 U. S. pint.
1 liter = 1000 c.c. = = 1.0567 U. S. pint.
1 decaliter = 10 litres = 2.6418 U. S. galls.
1 hectoliter = 100 litres = 26.418 U. S. galls.
1 kiloliter = 1000 litres = 264.18 U. S. galls.

Weights.

1 milligram = 0.001 gram = 0.015 grain Troy.
1 centigram = 0.01 gram = 0.154 grain Troy.
1 decigram = 0.1 gram = 1.543 grain Troy.
1 gram = 15.432 grains Troy.
1 decagram = 10 grams = 154.324 grains Troy.
1 hoctogram = 100 grams = 0.268 pound Troy.
1 kilogram = 1000 grams = 2.679 pounds Troy.

A—To convert degrees F. into degrees C.—The following formula is all that is necessary, the signs being carefully considered.

$$(F\text{-}32)\,\frac{5}{9}=C.$$

Examples.

(1)—Convert 50° F. to degrees C.

$$50-32=18\;;\;18\times\frac{5}{9}=10^{\circ}\text{ C.}$$

(2)—Convert -13° F. to degrees C.

$$-13-32=-45\;;-45\times\frac{5}{9}=-25^{\circ}\text{C.}$$

B—To convert degrees C. to degrees F.

$$\left(C\times\frac{9}{5}\right)+32=F.$$

Examples.

(1)—Convert 40° C. to degrees F.

$$40\times\frac{9}{5}=72:\;72+32=104^{\circ}\text{ F.}$$

(2)—Convert -10° C. to degrees F.

$$-10\times\frac{9}{5}=-18\;;\;-18+32=+14^{\circ}\text{ F.}$$

INDEX.

- Acetylene, 12
- Acid, definition of, 45
- Acid, acetic, 105
  - amic, 101
  - arsenic, 54, 93
  - arsenious, 54, 93
  - benzoic, 116
  - boracic, 25
  - butyric, 105
  - carbamic, 65
  - carbonic, 12, 54
    - test for, 122
  - carbolic, 115
  - chloric, 16, 54
  - chlorous, 15, 54
  - chromic, 88
    - test for, 128
  - citric, 109
  - formic, 105
  - gallic, 117
  - glycollic, 106
  - hippuric, 137
  - hydrochloric, 15, 54
    - test for, 34
  - hydrosulphuric, 19, 54
  - hydrocyanic, 13, 54
    - test for, 123
  - hydrochlorous, 15, 54
  - hypophosphorous, 25, 54
  - lactic, 106
  - linoleic, 108
  - malonic, 106
  - metaphosphoric, 25, 54
  - metastannic, 90
  - nitric, 10, 54
    - test for, 34
  - nitroso-nitric, 10
  - nitrous, 9, 54
    - test for, 34
  - oleic, 105
  - orthophosphoric, 25, 54
    - test for, 122
  - oxalic, 106
  - palmitic, 105
  - perchloric, 15, 54
  - propionic, 105
  - phosphorous, 25, 54
    - test for, 123
  - prussic (see Acid, hydrocyanic)
  - pyrochromic, 88
  - pyrogallic, 115
  - pyrophosphoric, 25, 54
  - pyrosulphuric, 22, 54
  - silicic, 23
  - sulphuric, 21, 54
    - test for, 34, 122
  - stannic, 90
  - stearic, 105
  - tannic, 117
  - tartaric, 109
  - thiosulphuric, 21, 54
  - uric, 137
  - valerianic, 105
- Acid halide, 100
- Acid oxide, 100
- Acids, aromatic, 116
- Acids, organic, 99
- Aconitine, test for, 139
- Air, 38
- Albumenoids, 118
- Albumin, 119
  - tests for, in urine, 138
- Alcohol, 98
  - ethyl or common, 102
  - methenyl, 107
  - methyl 101
  - propenyl, 107
  - sextone, 110
- Alcohols, aromatic, 114
  - diatomic, 105
  - hexatomic, 110
  - monatomic, 101
  - monatomic, acids of, 104
  - tetratomic, 109
  - triatomic, 106
- Aldehyde, 99
- Ale, 103
- Alkaloids, 117
  - tests for, 132
- Allotropic, 49
- Alloy, 49
- Aluminium, 80
  - compounds of, 80
  - tests for, 127
- Amalgam, 49
- Amides, 101
- Amines, 100
- Ammonia, 9
  - test for, 34
- Ammonium, 64

Ammonium, alcoholic, 100
  compounds of, 65
  test for, 34
Amorphous, 49
Amyloses, 110, 112
Analysis, biological, 36
  elementary or ultimate, 47
  proximate, 47
Anhydride, definition of, 45
Aniline, 116
Anthracene, 114
Anthracite, 11
Antimony, 91
  compounds of, 91
  tests for, 129
Apatite, 67
Aqua ammoniæ, 65
Aqua regia, 88
Aromatic compounds, characters of, 113
Arsenic, 92
  compounds of, 93
  tests for, 130
Asbestos, 69
Atmosphere, composition of, 38
  sources of pollution of, 44
Atomicity, 49, 52, 145
Atropine, test for, 132
Avogadro's law, 143
Baking-powders, 61
Barium, 66
  compounds of, 66
  test for, 124
Base, definition of, 45
Bases, 53
Basicity, 53
Beer, 103
Benzene, 97, 114
Benzol, 97, 114
Bile, in urine, 141
Bile-pigments, test for, 141
Bile-salts, test for, 141
Bismuth, 90
  compounds of, 90
  tests for, 129
Black-wash, 77
Boron, 25
Borax, 63
Brandy, 104
Brass, 74
Braunite, 86
Bromine, 16
Bromoform, 107
Bronze, 74
Cadmium, 71
  compounds of, 72
Caesium, 64
Caffeine, test for, 133
Calcium, 67
  compounds of, 67
  test for, 35, 124
Calamine, 70
Calomel, 75
Cane-sugar, 112
Carbamide, 65
Carbinol, 101
Carbohydrates, 110
Carbon, 10
  compounds of, 11
Carbon dioxide, test for, 36
Carbonates, test for, 122
Cellulose, 112
Cement, hydraulic, 68
Cerusite, 72
Charcoal, 11
Chemical affinity, 146
Chlorine, 14
  compounds of, 14
  test for, 34
Chloroform, 107
Chromates, test for, 128
Chrome-yellow, 72
Chromium, 87
  compounds of, 87
  test for, 128
Coal-gas, 13
Cobalt, 85
Codeine, test for, 134
Collodion, 113
Compound ether, 98
Condy's Fluids, 87
Conine, 118
  test for, 133
Copper, 73
  compounds of, 74
  test for, 125
Copperas, 85
Corrosive sublimate, 76
Creatinin, 138
Cyanides, test for, 123
Cyanogen, 13
Dalton's law, 142
Deliquescent, 49
Dextrin, 113
Dextrose, 110
  tests for, in urine, 140
Diamond, 10
Dimorphous, 49
Dolomite, 69
Double decomposition, 50
Dulong & Petit's law, 144
Dynamite, 108
Earthenware, 81
Efflorescent, 49
Elements, list of, 1
Epsom salt, 69, 70
Erythrite, 109
Ethene, 12
Ether, compound 98
  ethylic or sulphuric, 104
  haloid, 98
  oxygen, 98
  sulphur, 99

Ethylbenzene, 114
Fats, 107
Felspar, 23
Fermentation, methods for prevention of, 121
  products of, 103
  requisites for, 102
  varieties of, 120
Ferments, classes of, 120
Fluorine, 17
  compounds of, 17
Fluorspar, 67
Formula, empirical, 47
  graphic, 51
  molecular, 48
  type, 48, 51
Fowler's solution, 93
Galena, 72
Gas-carbon, 11
Gelsemine, test for, 133
Gin, 104
Glass, Bohemian, 82
  crown, 82
  flint, 82
  soluble, 23
Glucoses, 110
Glucosides, 111
Glycols, 106
Glycerine, 107
Gold, 88
  compounds of, 89
  tests for, 129
Graphite, 10
Green, Paris or Schweinfurt, 93
  Scheele's, 93
Ground-water, 28
Gums, 113
Gun cotton, 113
Gun-powder, 61
Gypsum, 67, 68
Haematite, red, 83
Halogens, properties of, 17
Haloid ether, 98
Hausmannite, 87
House-drainage, 40
Hydrocarbon, 97
Hydrogen, 6
  compounds of, 8
Hydroquinone, 115
Hyoscyamine, test for, 133
Hyoscine, test for, 133
Hypoxanthin, 138
Iceland spar, 67
Iodine, 16
Iodine and Iodides, test for, 123
Iodoform, 107
Iron, 82
  compounds of, 84
  dialysed, 84
  tests for, 127
Isomerism, 48
Isomorphism, 145
Isomorphous 49
Javelle water, 15
Ketone, 99
Labarraque's solution, 15
Lactose, 112
Lager, 103
Lamp-black, 11
Lead, 72
  compounds of, 72
  tests for, 125
Lead-plaster, 73
Levulose, 111
Lime, 67
Litharge, 72
Lithium, 64
Load-stone, 83
Lobeline, 118
Lunar caustic, 79
Magnesite, 69
Magnesium, 69
  compounds of, 69
  test for, 35
Malachite, 73
Manganese, 86
  compounds of, 86
  tests for, 128
Marsh-gas, 12
Meerscham, 69
Mercaptan, 99
Mercury, 75
  compounds of, 75
  tests for, 126
Metals, alkaline, 58
Metals, properties of, 58
Metals of the alkaline earths, 66
Metamerism, 48
Methane, 12
Methylated spirit, 101
Milk sugar, 112
Morphine, test for, 134
Mortar, 67
Naphthalene, 114
Narcotine, test for, 134
Nessler reagent, 77
Nickel, 86
Nicotine test for, 134
Nitrogen, 8
  compounds of, 9
Nitroglycerine, 108
Non-metals, list of, 2
  properties of, 2
Olein, 107
Olefiant gas, 12
Organic compounds, classification of, 97
  properties of, 96
Organic matter, test for, 35
Organo-metallic compounds, 100
Orpiment, 94
Ortho-phosphates, test for, 122
Oxygen, 3
Oxygen ether, 98

Oxygen, in combination in plants and animals, 3
Oxides, 4, 52
Ozone, 5
Palmitin, 107
Peptones, 119
    test for, in urine, 139
Phenol, 115
Phenylamine, 116
Phloroglucin, 115
Phosphate, acid, super or soluble, 68
Phosphate, reverted, 68
Phosphorus, 23
    acids of, 25
    compounds of, 24
    test for, 123
Pilocarpine, test for, 134
Plaster of Paris, 68
Platinum, 95
    compounds of, 95
Plumbism, chronic, 73
Polymerism, 48
Porcelain, 81
Potassium, 59
    compounds of, 60
    tests for, 124
Proteids, 118
    classification of, 119
    tests for, 119
Pyrolusite, 87
Pyrocatechin, 115
Pyrogallol, 115
Quinine, test for, 134
Radical, simple, 47
    compound, 47
Realgar, 94
Resorcin, 115
Rubidium, 64
Rum, 104
Rust, 85
Saccharoses, 110, 112
Salts, definition of, 45
    graphic formulæ of, 54
Salts of Mercury and Copper, graphic formulæ of, 56
Salts of the Iron group, graphic formulæ of, 57
Sarkin, 138
Selenite, 67
Selenium, 22
Series, homologous, 48
    isologous, 49
Silicon, 22
    compounds of, 23
Silver, 78
    compounds of, 79
    test for, 127
Soaps, 108
Sodium, 62
    compounds of, 62
    test for, 124
Sparteine, 118
Specific heat, 144
Starch, 112
Starches, 110, 112
Steatite, 69
Stearin, 107
Steel, 83
Stoneware, 81
Strontium, 67
Strychnine, test for, 135
Sugars, 110, 112
    in urine, 139
Sulphates, test for, 122
Sulphur, 19
    acids of, 20
    compounds of, 19
Sulphur ether, 99
Sulphuretted hydrogen, 19
Talc, 69
Tartar-emetic, 92, 109
Tannins, 117
Tellurium, 22
Tin, 89
    compounds of, 89
Toluene, 114
Turpeth mineral, 78
Type metal, 91
Urea, 65
    test for, 137
Urine, 136
    composition of, 137
    fermentations of, 136
Valence, 52, 145
Ventilation, 43
Veratrine, test for, 135
Vitriol, blue, 74
    green, 85
    white 71
Whiskey, 103
Wine. 104
Wollastonite, 67
Water, 26
Waters, mineral, 30
    atmospheric, 27
    classification of natural, 26
    detection of impurities in, 33
    ground, 28
    pond, lake and river, 29
    salt, 30
    sources and effects of impurities in, 32
    spring, 27
    well. 29
Xanthin, 138
Xylene, 114
Zinc, 70
    compounds of, 72
    test for, 125
Zinc-blende, 70
Zincite, 71

QD 41 S988m 1889

04530760R

NLM 05029752 4

NATIONAL LIBRARY OF MEDICINE